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THE OSTEOLOGY OF THE STEGANOPODES.

By R. W. Shufeldt, M.D.

At the present writing it is a little over nineteen years ago since I first paid any attention to the osteology of the steganopodous birds. My initial paper upon this subject was a brief one devoted to the osteology of *Phalacrocorax bicristatus* (*Science*, Vol. 2, No. 41, Nov. 16, 1883, pp. 640–642, 3 figs.).[1] The figures illustrating that paper have since been used in text-books on ornithology and zoölogy to some extent. As will be observed in the body of the present memoir, five years later I published another contribution to this subject, entitled "Observations upon the Osteology of the Orders Tubinares and Steganopodes" (Proc. U. S. Nat. Mus., Vol. XI., 1888, pp. 253–315, 43 figs. in text); and also in January, 1889, "Notes on Brewster's and the Blue-footed Gannet" (*The Auk*, Vol. VI., No. 1, p. 67). What I have done in the matter of fossil birds of this suborder, will be chiefly found in my memoir, "A Study of the Fossil Avifauna of the Equus Beds of the Oregon Desert" (*Jour. Acad. Nat. Sci. Phila.*, Vol. XI., Pls. XV.–XVII, (4to), Phila., Oct., 1892, pp. 389–425), and a number of abstracts of the same, subsequently published elsewhere, as in *The American Naturalist*, and *The Auk*. In 1894, in the Proceedings of the Zoölogical Society of London, I published a brief paper "On the Affinities of the Steganopodes" (Feb. 20, pp. 160–162), and in the *Ibis* of the same year, in a paper entitled "On Cases of Complete Fibulæ in Existing Birds," made a study of the fibula in the *Sulidæ* (Vol. VI., No. 23, London, July, 1894, Art. XXIX., pp. 361–366, figs. 1, 2). *The Auk* also published a paper of mine in October, 1894, making

[1] See also *ibid.*, p. 822; also Vol. III., No. 53, Feb. 8, 1884, p. 143; also a rejoinder to Dr. Theo. N. Gill, *ibid.*, III. No. 63, pp. 474, 475, Apr. 18, 1884.

certain references to these birds, it being entitled, "Notes on the Steganopodes and on Fossil Birds' Eggs" (Vol. XI., No. 4, pp. 337–339); and there was likewise a note published about them on November 6, 1894 (*P. Z. S.*, p. 608).

Since then and up to the present time, (October, 1902), no paper or publication of any importance whatever of mine has been published about the *Steganopodes*, and especially about their osteology. In this interim, however, I made, as far as the material at hand would permit me, a more or less extensive study of the osteology of the entire group. These researches from time to time were written out and with them incorporated the facts brought out in my earlier publications. As time passed on, too, Mr. F. A. Lucas, of the U. S. National Museum at Washington, published a number of very important and interesting papers on the osteology of the *Steganopodes*, and as two of the best of these were of no great length, they likewise, with their figures, are herewith incorporated.

Moreover, during the last seven or eight years, Mr. Lucas with great industry has collected together for the osteological collections of the U. S. National Museum the finest series of skeletons of steganopodous birds existing anywhere in any institution in the world. With great courtesy and marked generosity Mr. Lucas has placed all this material at my disposal, to be studied and utilized in the present connection, and for this and for many other favors in the same direction, altogether too numerous to mention, my most sincere thanks are due to that distinguished anatomist. I am greatly indebted, too, to the courtesy of the U. S. National Museum in allowing me to take to my residence in Washington, from time to time, specimens to be photographed by me, which latter, being reproduced, form the material representing many of the figures in my plates. My private collections have likewise furnished specimens not as yet existing in the U. S. National Museum, and, as will be seen, a number of these will also be found among my figures on the plates. I am also indebted to other persons who have kindly collected material for me, but I believe in each case such assistance is duly noticed in the body of the present memoir. It also gives me pleasure to extend my thanks to my wife Alfhild for having made a very fair and correct copy of the notes I have collected on the osteology of the *Steganopodes* for a number of years past, and these may now be presented in the following manner:

We have this suborder of birds very fully represented in the North American avifauna. Of the first family in it to be considered in this memoir,—the *Phaëthontidæ* or Tropic Birds, we have at least two good species, viz:—*Phaëthon flavirostris*, the Yellow-billed Tropic Bird, and *P. æthereus*, the Red-billed Tropic Bird. Gannets of the family *Sulidæ* are still more numerous, but they all belong, apparently, to the genus *Sula*. There is *S. cyanops, S. sula, S. brewsteri, S. gossi, S. piscator*, and finally, the well-known Gannet *Sula bassana*. The *Anhingidæ* or Darters, are represented by the common Anhinga, or Snake Bird, (*Anhinga anhinga*). Ornithologists have placed all our Cormorants in the genus *Phalacrocorax*, (*Phalacrocoracidæ*), and of them, species and subspecies taken together, there seem to be nearly a dozen varieties. Next we have three Pelicans of the family *Pelecanidæ;* these are *Pelecanus erythrorhynchus*, the American White Pelican; *P. fuscus*, the Brown Pelican; and lastly, *P. californicus*, the Californian Brown Pelican. Finally, there is the Man-o'-War Bird, *Fregata aquila* of the family *Fregatidæ*, — a conspicuous steganopod of tropical and subtropical coasts generally.

Newton has said "that the tropic birds form a distinct family, *Phaëthontidæ*, of the *Steganopodes* (the *Dysporomorphæ* of Professor Huxley), was originally maintained by Brandt, and is now generally admitted, yet it cannot be denied that they differ a good deal from the other members of the group;[2] indeed, Professor Mivart, in the Zoölogical *Transactions* (X., p. 364) will hardly allow *Fregata* and *Phaëthon* to be Steganopodons at all; and one curious difference is shown by the eggs of the latter, which are in appearance so wholly unlike those of the rest. The osteology of two species has been well described and illustrated by Professor Alph. Milne-Edwards in M. Grandidier's fine *Oiseaux de Madagascar* (pp. 701–704, pls. 279–281 a)."[3]

The same distinguished authority has remarked of the *Sulidæ* that "structurally the Gannet presents many points worthy of note, such as its closed nostrils, its aborted tongue, and its toes all connected by a web — characters which it possesses in common with most of the other members of the group of birds (*Steganopodes*) to which it belongs. But more remarkable still is the system of subcutaneous air-cells, some of large size, pervading almost the whole surface of the body, communicating with the lungs, and capable of being inflated or emptied at the will of the birds This peculiarity has attracted the attention of several writers—Montagu, Professor Owen, (*Proc. Zoöl. Soc.*, 1831, p. 90), and Macgillivray; but a full and particular account of the anatomy of the Gannet is still to be desired."

Some of our *Sulidæ*, as *S. sula, S. cyanops*, and *Sula piscator* are known as Boobies, from their apparent excessive stupidity, but which the writer pleases to call too little dread or fear of the great destroyer — man. Sailors are very prone to the taking of bird-life without stint and for no other purpose than amusement, whenever they get the opportunity upon lonely islands where sea-fowl abound. Myriad.

[2] *Sulidæ* (Gannet), *Pelecanidæ* (Pelican), *Plotidæ* (Snake-Bird), *Phalacrocoracidæ* (Cormorant), and *Fregatidæ* (Frigate-Bird).

[3] Newton, Al., F.R.S. Art. "Tropic-Bird," Encycl. Brit., 9th Ed., Vol. XXIII., p. 588, 1888.

of Penguins and Gannets have thus perished. Superficially a Booby is distinguished from a Gannet in that the former lacks the median stripe of naked skin over the region of the throat, so characteristic of the latter birds. As a rule, too, Boobies are tropical species, and breed in trees, and are of wide distribution.

Morphologically, the genus *Anhinga* has received more attention than any other of the Steganopods. "Beside the excellent description of the American bird's alimentary canal furnished to Audubon by Macgillivray, other important points in its structure have been well set forth by Garrod and Forbes in the Zoölogical *Proceedings* (1876, pp. 335–345, pls. XXVI.–XXXIII.; 1878, pp. 679–681; and 1882, pp. 208–212), showing among other things that there is an appreciable anatomical difference between the species of the New World and of the Old; while the osteology of *P. melanogaster* has been admirably described and illustrated by Professor Milne-Edwards in M. Grandidier's great *Oiseaux de Madagascar* (pp. 691–695, pls. 284–285). In all the species the neck affords a feature which seems to be unique. The first seven of the cervical vertebræ form a continuous curve with its concavity forward, but the eighth articulates with the seventh nearly at a right angle, and, when the bird is at rest, lies horizontally. The ninth is directed downwards almost as abruptly, and those which succeed present a gentle forward convexity. The muscles moving this curious framework are as curiously specialized, and the result of the whole piece of mechanism is to enable the bird to spear with facility its fishy prey." (Newton, Arts "Gannet," and "Snake-Bird," *loc. cit.*, p. 188.

Again we find the same eminent ornithologist under the article "Frigate-Bird"[4] declaring that that interesting Steganopod "was placed by Linnæus in the genus *Pelecanus*, and until lately its assignment to the family *Pelecanidæ* has hardly ever been doubted. Professor Mivart has, however, now declared (*Trans. Zoöl. Soc.*, X., p. 364) that, as regards the postcranial part of its axial skeleton, he cannot detect sufficiently good characters to unite it with that family in the group named by Professor Brandt *Steganopodes*. There seems to be no ground for disputing this decision so far as separating the genus *Fregata* from the *Pelecanidæ* goes, but systematists will probably pause before they proceed to abolish the *Steganopodes*, and the result will most likely be that the Frigate-Birds will be considered to form a distinct family (*Fregatidæ*) in that group. In one very remarkable way the osteology of *Fregata* differs from that of all other birds known. The furcula coalesces firmly at its symphysis with the carina of the sternum, and also with the coracoids

[4] "'Man-of-War Bird' is also sometimes applied to it, and is perhaps the older name, but is less distinctive, some of the larger Albatrosses being so called, and, in books at least, has generally passed out of use." [Man-o'-war Bird is the vernacular name given to this species in the A. O U. Check-list of North American Birds, and is the one in common use by ornithologists in the United States.]

of the upper extremity of each of its rami, the anterior end of each coracoid coalescing also with the proximal end of the scapula. Thus the only articulations in the whole sternal apparatus are where the coracoids meet the sternum, and the consequence is a bony framework which would be perfectly rigid did not the flexibility of the rami of the furcula permit a limited amount of motion. That this mechanism is closely related to the faculty which the bird possesses of soaring for a considerable time in the air with scarcely a perceptible movement of the wings can hardly be doubted, but the particular way in which it works has yet to be explained" (*loc. cit.*, Vol. IX., p. 786).

Among others, the birds we propose to consider osteologically in the present memoir constitute the ORDER STEGANOPODES of the Check List of the American Ornithologists' Union (1886, p. 106), where they are divided into the families *Phaëthontidæ, Sulidæ, Anhingidæ, Phalacrocoracidæ, Pelecanidæ,* and *Fregatidæ,* — a family arrangement adopted here. According to Reichenow the "Steganopodes" are an Order (IV.) of the NATATORES, and contain but three families, the *Graculidæ, Sulidæ,* and *Pelecanidæ,*[5] while Dr. Stejneger arrays them as follows:

Order X.	Superfamily.	Family.
STEGANOPODES.	(XVI.) Pelecanoideæ.	Pelecanidæ.
		Sulidæ.
		Phalacrocoracidæ.
		Anhingidæ.
	(XVII.) Fregatoideæ.	
	(XVIII.) Phætontideæ.	

Professor Fürbringer, in his great work, places the "Steganopodes" (a Gens) in his Suborder Ciconiiformes, of the Order PELARGORNITHES, and divides them into the *four* families *Phaëthontidæ, Phalacrocoracidæ, Pelecanidæ,* and *Fregatidæ.* A still different arrangement is proposed by Mr. Seebohm, and the place they are supposed to occupy in the system according to his views will later on be given by me in my Osteology of the *Tubinares.*

Garrod has said "The *Steganopodes,* which do not form so natural a family, in my eyes, as in those of many; for their myological formula is not the same in all, being

In *Phæthon* A. XY,
In *Sula* and *Phalacrocorax* AX,
In *Fregata* A,

[5] Die Vögel der Zoölogischen Gärten, 1882.

from which it may be inferred that *Phaëthon* approaches the *Ciconiidæ* and *Fregata* the Accipitres. They all possess the ambiens, cæca, a tufted oil-gland, and the four toes included in a web, which is but imperfectly developed in some. *Sula* and *Phalacrocorax*, with *Plotus*, form one family, *Phaëthon* another, *Fregata* a third, and *Pelecanus* a fourth." (Coll. Sci. Mem., p. 221.)

Dr. Sharpe does not concur in this opinion, and in his "A Review of Recent Attempts to Classify Birds" (Budapest, 1891) places this group betwixt the Anseriformes and the Cathartidiformes, thus:

Order (XXIII.)	Suborders.	Families.
	Phaëthontes - - -	Phaëthontidæ.
	Sulæ - - - - - -	Sulidæ.
PELECANIFORMES.	Phalacrocoraces -	Phalacrocoracidæ.
		Plotidæ.
	Pelecani - - - -	Pelecanidæ.
	Fregati - - - - -	Fregatidæ.

In volume I of his "Hand List" (page 232), recently issued, this arrangement is somewhat changed. There the Pelecaniformes stand between the Ichthyornithiformes (Order XXII.) and the Cathartidiformes (Order XXIV.). They are then divided into the eight following families, viz.: 1. Phalacrocoracidæ. 2. Odontopterygidæ. 3. Plotidæ. 4. Sulidæ. 5. Fregatidæ. 6. Phaëthontidæ. 7. Pelecanidæ. 8. Pelagornithidæ. Of these 2 and 8 are extinct groups (1899).

Nearly a quarter of a century before Sharpe's work appeared Huxley in his P. S. Z. memoir (1867) had placed the steganopods in his group Dysporomorphæ of the Desmognathæ, and had said of them: "The rostrum is long and pointed and more or less curved, and the external nasal apertures are very small.[6] There are no basipterygoid processes. The palate-bones unite for a considerable distance behind the posterior nares, and send down a vertical crest from their junction."

"The maxillo-palatines are large and spongy. The angle of the mandible is truncated. The sternum is broad, and its truncated posterior edge is either entire or has a shallow excavation on each side of the middle line.

"The hallux is turned forwards or inwards, and is united by a web with the completely webbed anterior toes. The ratio of the phalanges is as in the preceding genera.

"The oil-gland is surmounted by a circlet of feathers.

[6] They are now known to be entirely absent in some of the genera as *Sula* and others.—S.

"This group answers to the 'Steganopodes' of Illiger; and since the appearance of the admirable memoir of Brandt, 'Zur Osteologie der Vögel,' in 1840, no doubt can have been entertained as to its extremely natural characters. The genera composing it are sharply divided by the structure of the skull, described above, into two groups — the one containing the Pelicans, the other the remaining genera" (pp. 461–462).

Doctor Hans Gadow makes an Order 9 — the Procellariiformes, and an Order 11, — the Falconiformes, — between which he places his Order 10, — the Ardeiformes. These last are thus characterized:

10. ARDEIFORMES.

Cosmopolitan Aquatic.
Young passing through a downy stage.
Oil-gland tufted. Aquito-cubital.
Humero-coracoid deep. No ectepicondylar process.
Desmognathous. No basipterygoid processes.

I. STEGANOPODES.

Cosmopolitan. Aquatic-nidicolous.
Piscivorous.
Rhamphotheca compound. Nares impervious.
No supraorbital glands. Angulare truncated.
Neck without apteria.
Legs short; all the four toes webbed together. (*Unique.*)
Hypotarsus complex. Flexors type of II.
Orthocœlous type II. Tongue rudimentary.

1. *Phaëtontidæ.*

15 cervical vertebræ.
Procoracoid process large.
Garrod's symbol AXY +.

2. *Phalacrocoracidæ* (including Sulinæ, Plotinæ, Phalacrocoracinæ).

18–20 cervical vertebræ.
Garrod's symbol AX +.

3. *Pelecanidæ.*

17 cervical vertebræ.
Procoracoid process small.
Garrod's symbol A +.

4. *Fregatidæ.*
   15 cervical vertebræ.
   Procoracoid process small.
   Garrod's symbol A + .

II. Herodii.
   Cosmopolitan. Waders. Nidicolous.
   Zoöphagous. Bill long, pointed, laterally compressed, with simple rhamphotheca. Nares pervious.
   No supraorbital glands.
   Neck long, with long apteria.
   Downs of adults only upon the apteria. (*Unique* among Ardeiformes.)
   Legs long; four toes not webbed.
   Hypotarsus complex. Flexors of type I. or VII.
   Orthocœlous. Type II. Cæca rudimentary.
   Tracheo-bronchial muscles attached to second bronchial rings.

1. *Ardeidæ.*
   19 or 20 cervical vertebræ.
   Several pairs of powder-down patches.
   11 primaries. — Cosmopolitan.

2. *Scopidæ.*
   16 cervical vertebræ.
   No powder-down patches.
   10 primaries. — Ethiopian.

III. Pelargi.
   Cosmopolitan. Waders.
   Neck long, without apteria. Nares pervious.
   Rhamphotheca simple.
   Legs long. Hypotarsus simple.
   Intestinal type IV. telogyrous.

1. *Ciconiidæ.*
   Zoöphagous. Nidicolous.
   17 cervical vertebræ.
   Hallux long, toes not webbed.
   Flexors of type I.
   Tongue rudimentary.
   Cæca rudimentary.
   Syrinx without Tracheo-bronchial muscles.

2. Phœnicopteridæ.
   Tropical. Nidifugous.
   18 or 19 cervical vertebræ.
   Hallux small, front toes webbed. Flexors of type IV.
   Tongue large and thick.
   Cæca functional.
   Syrinx with tracheo-bronchial muscles.

In 1889, as has been stated above, the present writer contributed some brief "Observations upon the Osteology of the Orders Tubinares and Steganopodes" to the Proceedings of the U. S. National Museum (pp. 286–314), and so far as the steganopodous birds were concerned there appeared in that article an illustrated account of the skeleton of *Sula bassana;* some remarks, also with figures, on the osteology of Cormorants and the Brown Pelican. That paper, with its figures, will be incorporated into the present memoir, but at this writing I am better off for osteological material wherewith to render a description of the skeletal characters of this suborder. My observations at this time are based principally but by no means altogether upon a study of the following skeletons and parts of skeletons.

List of Material.

Name.	Material.	Remarks.
Phaëthon flavirostris.	Perfect skeleton.	No. 17,841. Smithsonian collections.
Phaëthon æthereus.	Four perfect skeletons.	Author's collection. The gift of E. J. Reed Esq., of Guaymas, Mexico.
Sula bassana.	Skeleton nearly complete.	No. 16,643. Smithsonian collections.
Sula piscator.	Skeleton.	" 18,739. " "
Sula cyanops.	"	" 18,542. " "
Sula gossi.	Three complete skeletons.	Author's collection. The gift of E. J. Reed, Esq., of Guaymas, Mexico.
Sula brewsteri.	" " "	Author's collection. The gift of E. J. Reed, Esq., Guaymas, Mexico.
Anhinga anhinga.	Skeleton.	No. 18,259. Smithsonian collections.
Phalacrocorax urile.	"	" 18,982. " "
Pelecanus fuscus.	Skull and mandible.	Author's collection.
Pelecanus fuscus.	Skeleton.	No. 18,483. Smithsonian collections.
Fregata aguila.	"	" 18,485. " "

ON THE SKELETON IN PHAËTHON.[7]

Of the Skull, etc.—Of the two species of Tropic Birds, which we have to consider here, the red-billed one is the larger species, and this difference is quite apparent in their skulls, though in other particulars they are very much alike. In *P. æthereus*

[7] Dr. Sharpe, in his recent *Hand-List of Birds* (1899, Vol. 1, p. 238), recognizes the following species of *Phaëthon* as representing the genus throughout the world, viz: *P. rubricauda*, *P. lepturus*, *P. fulvus*, *P. americanus*, *P. æthereus*, and *P. indicus*. In this enumeration *P. americanus* and *P. flavirostris* are one and the same species.

the skull has an average length of about 10.8 centimeters, while in the other form, *P. flavirostris*, it equals for the same measurement but 9.2 centimeters. Measuring from the mid-point of the cranio-facial hinge, we find that in the yellow-billed species the length of the supero-mandibular portion of the skull exactly equals in length the cranial part, while in *P. æthereus* the facial portion slightly exceeds the cranial. Viewed from above (Plate I., Fig. 3), it will be seen that the supero-mandibular moiety is distinctly marked off from the cranium by the very distinct transverse cleft forming the cranio-facial hinge, which latter admits of considerable mobility in the dried skull. The upper osseous bill is broad and massive at its base, but almost immediately tapers as we proceed anteriorly towards its acute apex. The culmen is slightly decurved, while below the latero-external margins are cultrate. Just within these there runs a furrow nearly to the apex, which is bounded mesially by a raised bony ridge. Internal to this again, the central portion, is excavated, from the maxillo-palatines to the apex, being broad posteriorly and gradually tapering to the front. A delicate medio-longitudinal ridge

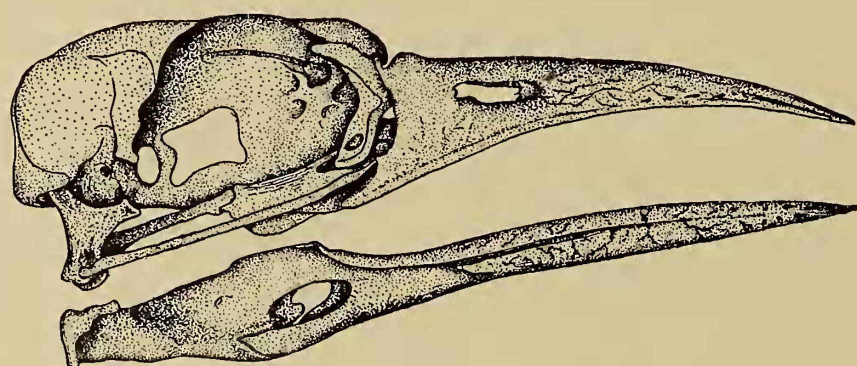


Fig. 1. Right lateral view of the skull of *Phaëthon æthereus*. Natural size. Drawn by the author from a specimen in his own collection.

marks the anterior half of this space, which is about equally well marked in the two species. In these birds there is always found a small foramen, perforating the mandible upon either side, just anterior to the lateral terminations of the cranio-facial cleft; while beyond these, the narial apertures, one upon either aspect of this osseous beak, are seen to be of no great size, being in form elongated, ellipsoidal, communicating, and with smooth, rounded margins. Minute marginal and culminar foramina occur in this part of the skull, while the intervening surface, or what is really the sides of the upper osseous mandible, is delicately scrolled over with fine anastomosing venations (Fig. 1).

The rhinal chamber is somewhat capacious, and the hollow part of this region, clear to the apex, is more or less filled in with bony tissue of the cancellous variety, The cranium is broad and spreading behind, and but moderately narrowed anteriorly, and this form defines the shape of the superocranial aspect of the skull, where the smooth, rolling frontal portion is succeeded, as we pass backwards, by the flat and wide space that separates the sharp marginal borders of the orbits above. Slight parial elevations characterize the parietal region, and this surface falls away gradually, upon either side, towards the post-frontal processes. Deeply sculpt, the crotaphyte fossæ are mesially separated by a broad interval, smooth and unmarked. A remarkable feature of the skull of one of these birds, and it is still further enhanced when the lower mandible is articulated, is the appearance it has of having been vertically truncated in the transverse plane or direction, or being cut squarely across, reminding us of the skull in certain Herons and their allies.

Regarding the skull of a Tropic Bird, upon its lateral aspect, we are at first struck with the large, squarish orbit, bounded below by the straight, stout zygomatic bar; posteriorly by the massive quadrate, and the spreading post-frontal process; anteriorly, by the great, free lacrymal bone, with its projecting upper limb, and its vertical portion, which latter is twice perforated posteriorly by conspicuous pneumatic foramina. The interorbital septum invariably presents a large quadrilateral vacuity at its central surface, which is usually distinct from the orbital foramina posterior to it. A mere apology in bone represents the almost thoroughly aborted ethmoidal wing, or *pars plana.* The foramen for the exit of an olfactory nerve is exceedingly small as it occurs upon the anterior wall of the brain-case, and the groove leading from it is open; but the anterior foramen seen above the semi-aborted *pars plana* is of considerable size, and is usually completely surrounded by bone. In front, the margin of the mesethmoid is deeply notched, being produced below as a conspicuous, blunt-pointed process,—just the reverse, for example, of what we find in *Sula.*

Turning to the inferior aspect of the skull we meet with many points of interest, and a construction of parts by no means typically steganopodous (see Plate I., Fig. 2). In front the *maxillopalatines* are distinctly developed, being elegant concavo-convex processes, with their convex sufaces parallel with each other but not in contact mesially. Their concave external aspects are partially filled with a very open cancellous tissue of bone, and they have a broad base in each case, which appears in the adult skull to coössify with the corresponding nasal, maxillary, and perhaps, premaxillary. The postero-inferior angles of the latter are, upon either side, produced backwards as a prominent process which, when the lower mandible is articulated with the skull, outwardly overlaps its margin opposite to them.

The *palatines,* although in contact for their entire surfaces in the middle line, do not coössify as is the case in the Cormorants, Gannets and other steganopods.

Either one of this pair of bones is thickened, much cut away posteriorly, but broadly wedged in among the usual facial elements in front. Above they are moulded closely upon the rounded rostrum of the sphenoid, being drawn to a fine point anteriorly. It is along this line beneath that the palatines fuse with the *vomer*, an element which has much in its form to remind us of that bone in the *Laridæ*, being pointed in front, mesially carinated below, and grooved longitudinally along its upper surface. Laterally, the surface of a palatine looks almost directly outwards, and it is here that we invariably find one or more pneumatic foramina leading into the interior of the bone. A palatine head is large and offers an ample articulatory surface for the corresponding pterygoid. These palatal heads are closely pressed together, but in front of them, below, the bones send down in common only the merest suspicion of a midcarination, a character so common in *Pelecanus*, Cormorants, and other species of the suborder. The postero-external angle of a palatine can hardly be said to exist in the skull of this bird, as the bone so abruptly slopes away in that part of its body, as will be observed by referring to the figures in the plates.

The *pterygoids* are long, stout, straight, subcylindrical, rod-like bones, cupped at their extremities, and when articulated *in situ*, stand well above the basitemporal area. Not a semblance of such a thing as a basipterygoidal process is to be discovered upon either of them, or at the anterior borders of the basisphenoid. Anteriorly, their palatine heads articulate in contact with each other; their divergence from this point is at an angle of about 20°.

The basitemporal area is triangular in form with a small transverse ridge crossing its center. In front a broad, anteriorly rounded lip of bone underlaps the double openings for the internal carotid. So prominent in *Sula*, the paroccipital processes are here much reduced in size, and the hemispherical condyle is sessile and unnotched on its superior aspect. The foramen magnum is subcircular in outline, and is situated, as it were, in the middle of a shallow concavity.

A *quadrate* has an extensive anterior surface; transversely elongated, antero-posteriorly compressed, articular facet for the mandible; a double mastoidal head; and a broad, squarely truncated orbital process. This bone is also pneumatic, and its articular facet for a pterygoid is rounded and projecting. As in *Sula*, there is a very deep pit, of no mean size, immediately in front of the mastoidal process of either quadrate, and when those bones are *in situ*, they arch over the posterior thirds of these pits, in such a manner as to have, in each case, the outer mastoidal head articulate upon the outer border of this pit, and the inner head upon the inner border. Either one of these deep excavations is situated above and to the outer side of the corresponding osseous opening of the ear, and the foramen ovale. Posteriorly the cranial surface, in so far as the occipital area is concerned, lies in the vertical plane, and is distinctly reniform in outline, bounded all about by a raised osseous ridge, with its convex curve above, and the foramen magnum situated mesiad in the concavity below. The unpierced supraoccipital prominence is fairly well-developed, and occupies the mid-vertical line of this reniform occipital area, extending from the foramen to the limiting curve above.

The *mandible* of a Tropic Bird is somewhat acutely V-shaped in form with large and deep articular cups for the quadrates. These cups have large pneumatic foramina in their concavities, with a single such opening on the upper side of their short inturned processes. Behind, they are vertically, as well as completely, truncated.

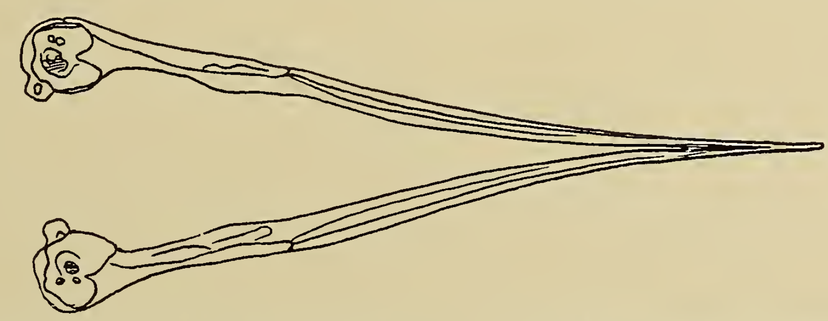


FIG. 2. Superior view of mandible of *Phaëthon æthereus*. Outline sketch, natural size, by the author from specimen in his private collection.

Either ramal moiety is very deep, and laterally compressed,—presenting, well forward of the articular end, a large, irregular ramal vacuity. The dentary portions of the mandible have hardly half the height of the ramal limbs; they are thickened, and each is deeply grooved for nearly the entire length of its superior margin. Anteriorly, they run very close to each other, and the terminal symphysis is deep, averaging in depth 1.5 cm. in *P. æthereus*, being nearly 2 cm. in some specimens. In an *eye* of the species just mentioned I count some 15 osseous sclerotal plates; they are remarkable for the extensive manner in which they overlap each other, and still more for the fact that the anterior ones have a depth of not more than one third of the posterior ones, a uniform graduation taking place in the intermediate plates, above and below, in this osseous circlet.

We find, too, an interesting structure in the bony parts of the *hyoidean apparatus* of *Phaëthon*. In the adult, the ceratohyals have fused in ossification with the posterior half of the glossohyal to form a peg-like bone, which is longitudinally grooved above and convex below. The first basibranchial is a short, thick piece, expanded in front to form an articular facet, while behind it supports the very minute, though free, second basibranchial. Either ceratobranchial is an extremely long, slender rod of bone, bearing at its distal end a little bit of an epibranchial, which latter is finished off posteriorly by a thread-like extension in cartilage. Cartilage also tip the glossohyal in sfront, and laterally, the ends of the ceratohyals may not entirely ossify.

For the *trachea*, its rings seem to be performed in elementary osseous tissue only, and in mid-course of this tube, they are delicate structures, being markedly narrow in depth, and very frail.

Of the Axial Skeleton.—(See Plate XXI., Figs. 5 and 6.) Representatives of the genus *Phaëthon* possess in the cervical and cervico-dorsal divisions of the vertebral chain 15 bones. Three of these are cervico-dorsals, the anterior one of which always supports an exceedingly rudimentary pair of free riblets.

In *P. æthereus* they are seen to be in the same condition on the next following vertebra, or the 14th vertebra of the neck, while in *P. flavirostris* they are of some considerable length, though they do not develop epipleuræ. Both species have a well-developed pair of ribs on the 15th segment of the neck vertebræ, that support epipleural spines on their posterior margins, to which part they are firmly coössified.

The *atlas* is comparatively small with rather slender neurapophyses. Its cup is profoundly notched above, for the accommodation of the odontoidal process of the axis. Below, it develops a low hypapophysial spine projecting backwards, which, when the bones are articulated *in situ*, underlaps the centrum of the second vertebra. A prominent, quadrate hypapophysis also is found to exist beneath the centra of the axis and third vertebra, but this feature is very nearly aborted on the fourth cervical.

On the *axis vertebra* we find a massive neural spine, with conspicuous lateral projections, each jutting upwards and outwards from above the postzygapophyses. All these characters are moderately reduced in the third vertebra, while in the fourth the neurapophysis is very much reduced in size, and the aforesaid lateral or anapophysial processes are all but absent.

The lateral vertebral canals are but semi-closed in the axis; they are thoroughly so throughout the rest of the vertebral chain until we meet with the leading cervico-dorsal, wherein the existence of a pair of rudimentary free pleurapophyses leaves these canals open.

On the under side of the cervicals, the passage for the carotid canal is seen to be wide open, and is confined to the 5th, 6th, 7th and 8th vertebræ. Throughout the series, beginning with the third cervical, we find the parial backward projecting spines of the parapophyses to be pointed, and exceedingly stumpy and very short.

On the 9th a median hyapophysis makes its appearance, which is larger on the 10th, more quadrilateral in form and laterally compressed on the 11th, small on the

12th, and still more so on the cervico-dorsals, where there coexists with it the barest suspicion of lateral spines.

Viewed dorsad, the third cervical appears to have a quadrilateral form, which passes to the more oblong shape in the fourth, and the bones of this part of the column commence to shorten antero-posteriorly with sixth, they being wider than they are long for the remainder of the spinal series. The last two cervico-dorsals develop a low, quadrilateral neural spine, which resembles, but is antero-posteriorly shorter than the same process as it occurs throughout the dorsal vertebræ.

P. flavirostris has a delicate, osseous, interzygapophysial bar, extending from the back of either prezygapophysis backwards and inwards to the corresponding anterior bases of the postzygapophyses, in the fifth, sixth and seventh cervical vertebræ. Usually it only ossifies in the fifth and sixth in *P. æthereus*, its place being taken by ligament in the seventh and eighth. No such character as this is ever present in any of the *Sulidæ*. Strong and broad diapophysial processes are first pronounced in the first and second cervico-dorsals; in the last cervico-dorsal these processes are markedly shorter and shallower, while throughout the dorsal series of vertebræ they are decidedly slenderer, and in their vertical diameters of very little thickness.

Passing to the dorsal series of vertebræ, we find in *P. flavirostris* six of those bones freely articulated with each other between the last cervico-dorsal and the leading one in the consolidated pelvic sacrum. This last-mentioned vertebra, in all my specimens of *P. æthereus*, coössifies with the anterior sacral, though, as we shall see presently, this difference does not affect either the number or the arrangement of the thoracic ribs. Hypapophyses are fairly well developed upon all the dorsals of the middle of the back, but they become small as we near the pelvis, to be very inconspicuous or entirely absent from the last one or two bones. Pneumaticity characterizes all the vertebræ between the atlas and the first caudal, and the centra of the dorsals are but moderately compressed in the transverse direction. They present the usual ornithic plan of articulation with each other, and the same may be said of the manner in which the true *ribs* are connected with the segments of this division of the spinal column. There are *five* pairs of these ribs that bear *uncinate processes*, firmly attached to the middle of their hinder borders, and each pair of these appendages is slender, slightly overlapping the succeeding rib in every case save the last, which may or may not be of sufficient length to do so. As for the ribs themselves, they, too, are long and narrow, sweeping well backwards, a fact that entails the presence of lengthy hæmapophyses to reach the sternum. These latter are of no great caliber; the first pair being nearly straight, and the succeeding pairs becoming gradually more curved as we approach the last ones, which are the most so. Finally, there are two pairs of thoracic ribs that are devoid of unciform processes, the costal ribs of the first of which reach the sternum, but those of the ultimate pair fail to do so by some considerable distance in both species. From what has been said in a foregoing paragraph, it will be seen that this gives one true pair of "pelvic ribs," while the penultimate pleurapophyses and their hæmapophyses in *P. flavirostris* articulate with a vertebra of the dorsum which is free, but which in *P. æthereus* is coössified with the pelvic sacrum. So were we to have studied skeletons of the latter species only, it would have been said that it possessed *two* pairs of "pelvic ribs," and had *P. flavirostris* alone been examined in this particular, the descriptive osteologist would have recorded but one pair. This is but another instance exemplifying the great necessity of having the proper material in sufficient variety before one for comparison.

Viewing the *pelvis* from above, we find that the anterior margins of the ilia overlap the penultimate pair of thoraric ribs in the Red-billed Tropic Bird, not so, however, *P. flavirostris;* and this, taken in connection with the apparent appropriation on the part of the sacrum of one of the dorsal vertebræ, already referred to above, in the case of the first-named species, lends to the pelvis a difference of appearance in the skeletons of the two birds, now under consideration, which is not otherwise particularly borne out by this bone. In part, the pelves of these specimens are otherwise very much alike. Disregarding, then, the vertebra to which reference has just been made, we find the *sacrum* to be composed of *ten* others, which are thoroughly fused together and with the ilia, one upon either side. Taken as a whole, the pelvis is broad, not especially long, and very shallow and compressed in the vertical direction. The internal borders of the ilia are nearly parallel to each other, and the broad sacrum keeps them well apart for their entire length. Such an arrangement, as we might expect, gives open, shallow "ilio-neural grooves," one on either side of the sacral crista, anteriorly. These are quite continuous with similar "groovings" carried back posteriorly as far as the first caudal vertebra. In other words, between the inner borders of either ilium, and the supero-median line of the sacrum, the diapophyses of the vertebræ are found to be below the general surface; while between them, for the entire length of the pelvis, occur foramina of some size, and more or less subcircular in outline. These single parial rows of interdiapophysial foramina constitute a striking character upon the superior aspect of the pelvis of the Tropic Birds, inasmuch as in the preacetabular portion of that bone in *Sula, Plotis*, the Pelicans, and the Cormorants, they are out of sight on this aspect by the internal margins of the ilia meeting the sacral crista. Thus it will be appreciated that the breadth of the pelvis in *Phaëthon*, to which allusion has been made, is chiefly due to the broad sacrum, and not to the ilia, which bones, either in their pre- or postacetabular parts, are quite narrow in their transverse direction. The former area, in each one, being very slightly concaved, and in the latter, barely convexed. Antitrochanterian processes are comparatively prominent, and each overhangs a cotyloid cavity of moderate size, and of the usual ornithic character. Laterally viewed, we note that the *obturator foramen* is complete, due to the fact that either pubic style is in contact for nearly its entire length with the inferior margin of the corresponding ischium. This obliterates anything like an obturator space. Each *pubic style* is long and somewhat slender, and often passing an ischium behind, curves downwards and very slightly inwards. Here the bone is appreciably dilated in *P. æthereus*, which is not the case in the other species we are considering. An *ischium* is also narrow, and projects some distance beyond the ilium of the same side. A very shallow ilio-ischiac notch, on the posterior pelvic border, is formed by this arrangement; but by no means as well marked an one as we see in the more typical steganopods, to be described later on in this memoir.

The ilio-ischiac foramen is large and of a subelliptical outline (see Fig. 6, Pl. XXI.). On the under side of the pelvis in *Phaëthon*, we are to note the fact that the sacral vertebræ, opposite the acetabula, do not throw out their processes to act as braces to especially strengthen the ilio-pelvic walls at those points, a feature often seen in the skeletons of other birds, and, as before found, both by Mivart and myself, to be the case in *Pelacanus*, the true cormorants, in *Sula*, and to a somewhat less conspicuous degree in *Anhinga*.

Eight free *caudal vertebræ*, plus an elongated, ploughshare-shaped *pygostyle*, go to make up the skeleton of the tail in a Tropic Bird. These vertebræ have spreading diapophyses, especially the fifth one, and all have neural spines, while the last three of them possess bifid hæmal spines; and this last character is impressed upon the lower end of the coccyx. The neural canal passes through the entire series. From this, and including the coccygeal piece, it will be seen, from our account of the spinal column, as it has been given above, to contain in these birds, forty vertebræ. They are all pneumatic, except the atlas and those which go to form the skeleton of the tail.

The Sternum.—This bone in my specimen of *Phaëthon flavirostris* has a body of a quadrilateral form, being almost as wide as it is long. Its carina is deep anteriorly, where it protrudes far forwards, while behind it merges with the ventral surface of the body at some distance before it reaches the mid-xiphoidal process. In front the carinal angle is thickened, and upon its superior aspect there exists a considerable facet for articulation with infero-median surface of the *os furcula.* This facet is not at the apex, but is found about one third the distance back towards the sternal body, and the articulation, though very close and extensive, is free, and anchylosis has never been seen by me to take place between the two bones. The *coracoidal grooves* decussate, the median extremity of the right one passing beneath the median extremity of the left. A very rudimentary manubrium is seen immediately below this point, and below it a circular pneumatic foramen. Either *costal process* is broad and subtriangular in form, and upon either costal border occur six facets for articulation with the hæmapophyses which connect the sternum with the vertebral ribs. On the much-concaved sternal body, just within the anterior border in the median line, dorsad, there runs back longitudinally a characteristic bridge of bone, upon either side of which we find a large subelliptical pneumatic foramen, and usually they are the only two found in this situation. Other small ones occur, however, in the pitlets among the hæmapophysial facets on the costal borders. Very broad external xiphoidal processes of the posterior part of the sternal body, extend further backwards than any other part of the bone; the middle xiphoidal process is broadly rounded. The internal pair of processes are small and delicate, and each one of the pair occupies a mid-point in the great, round notch, on either side, existing between the mid- and external xiphoidal process, thus creating a 4-notched sternum for this species, of a peculiar pattern in this respect. Mivart has said in his "Axial Skeleton of the Pelecanidæ" (T. Z. S., p. 365), that "in the *Pelecanidæ* there is but a single lateral xiphoid process on each side, while in *Phaëthon* there are two on each side, in addition to the median xiphoid process." Farther on we shall see that this by no means always holds good for *P. æthereus.* Passing next to the consideration of the sternum in the species last mentioned, we observe that in the majority of its characters it agrees with the bone as it has just been described for *P. flavirostris.* It is proportionately larger however, and presents two striking differences. In the first place, in all four of my specimens a large, blunt-pointed manubrium is present, which is transversely pierced at its base by a foramen. Again, the internal pair of xiphoidal processes may be entirely absent, or only one may be present on one side, and when such is the case, it appears only as a minute projection from the inner border of the external xiphoidal process *near its extremity.* I have no specimens of the sternum of *P. æthereus* wherein there is to be found a *pair* of internal xiphoidal processes, and consequently its sternum is not four-notched as in its cogener, *P. flavirostris.* More or less minute or scattered pneumatic foramina may be found on its thoracic surface, above the two large ones which occupy similar positions to those noticed in the Yellow-billed Tropic Bird.

The *os furcula* is of the broad U-shaped pattern, with its median portion below, widened, and on the under surface of which occurs the facet for articulation with the keel of the sternum as described above. The upper free extremities of the clavicles are drawn out, rounded, blunt-pointed and the apex of each one, when articulated *in situ*, reaches back, on either side, to the antero-mesial angle of the corresponding scapula.

A *scapula* is long, very narrow, rounded, and somewhat compressed in the vertical direction. Its distal end only is blade-like, very slightly expanded, and obliquely truncated from a point within to the apex. It articulates in the usual ornithic manner with the coracoid, and neither it nor the os furcula appear to be pneumatic, as is the *coracoid*. This latter bone of the shoulder-girdle has a broad, much expanded sternal extremity, which supports a moderately prominent lateral coracoid process. The entire length of the bone is greater than half the length of the humerus, and its shaft is compressed in the oblique antero-posterior direction. Its head or summit is tuberous, and also somewhat compressed in the same plane with the shaft. The process for articulation with the os furcula is large, much flattened from side to side, and low down in the deep tendinal groove it creates, we observe a minute antero-posterior perforation of the bone. As usual, the coracoid and scapula form a well defined *glenoid cavity* for articulation with the head of the humerus. An *os humero-scapulare* is not found.

Of the Appendicular Skeleton. The Pectoral Limb: Apart from the mere matter of the difference in size, the bones composing the limbs in the skeletons of these two species of *Phaëthon* are in their corresponding characters almost exactly alike, and these again are notably different from those same characters as we find them exemplified in the limb-bones of the skeletons in other families of the Steganopodes. These departures will be noted from time to time later on in this paper, after the present account of the osteology of the Tropic Birds has been written.

In the brief subjoined table some of the lengths of the bones are compared, the measurements being given in centimeters and fractions.

TABLE.

Measurements, taken from extreme distal points, and not on curved contour lines.	Species.	
	P. flavirostris.	*P. æthereus.*
Length of humerus.	8.4	9.3
Length of ulna.	8.9	9.7
Length of carpo-metacarpus.	4.3	4.8
Length of proximal phalanx of index digit.	2.5	2.9
Length of distal phalanx of index digit.	2.4	2.8
Total length of pinion (articulated).	8.8	10.1
Length of femur.	3.2	3.7
Length of tibio-tarsus.	4.7	5.3
Length of tarso-metatarsus.	2 3	2.8
Length of mid anterior toe.	3.8	4.2

From this it will be seen that both the proportionate and relative lengths of certain long bones of the limbs in these two species of birds slightly differ, but the difference is very slight.

There is no especial association of characters in either the pectoral or pelvic limbs of *Phaëthon* that in any way remind us of the corresponding parts of the skeleton in a Gull, or a Tern, much less any kind of an Auk or a Puffin. The several bones seem to possess a distinctive character quite their own. The *humerus* shows a slight compression in the transverse direction, rendering its humeral head narrow, and its very moderately curved shaft ellipsoidal rather than circular on section. The well-marked ulnar tuberosity projects directly anconad, as does the prominent radial crest project palmad,—the long transverse axis of the first being parallel to the plane of the latter. At the proximal end of the bone, on its palmar aspect, just before we come to the humeral head, we meet with a well-defined groove running at right angles to the long axis of the shaft; and this groove becomes very deeply marked at a point on the opposite side of the bone from the ulnar tuberosity.

The "pneumatic fossa" instead of being entirely open, as in a good many birds, is covered across by a more or less perfect bony plate, which plate shows the single, circular pneumatic perforation at its center. This hole is smaller in proportion in my specimen of *P. flavirostris* than it is in the other species. At the distal end of the bone the fossa above the *oblique* and *ulnar* tubercles is fairly well scooped out; while on the ulnar side of the humerus at this end, both the pits for tendinal insertion and the grooves for their passage are unusually well marked and deep. An exceedingly rudimentary "epicondyloid process" can be seen, but it by no means is the characteristic feature that we find it to be in the humeri of the *Laridæ* and those suborders of birds most nearly related to them.

The *radius* is straight and of a more or less uniform caliber, while its companion bone of the antibrachium, the *ulna*, is considerably bowed, with its shaft presenting three faces more or less distinctly. These might be here designated as a palmar face or surface, an interosseous face, and a subanconal face. The line or angle formed by the intersection of the subanconal and palmar faces, has along it the row of papillæ of the secondary quill-feathers; and another indistinct row of them passes down the middle of the subanconal surface. There are fourteen such papillæ in the first mentioned row. The olecranon process is a very insignificant affair, while at the distal extremity of the bone, at its anconal side, the end is drawn out into a distinct apophysis, which, in articulation, bends down towards the *ulnare ossicle* of the wrist. Two segments compose the skeleton of the carpus in the adult, the usual *radiale* and the just-mentioned *ulnare.*

Carpo-metacarpus presents us for examination the ornithic characters common to many representives of this class of vertebrates. The coössified pollex metacarpal is of average size, and the slender shaft of the medius metacarpal is, for the greater part of its continuity, parallel with the far heavier shaft of index. This last, at the anterior aspect of its distal end, develops a pronounced little process, which serves to retain in their proper groove, the tendons which pass in that region during the life of the individual. The free digit of pollex has the usual form seen in *Aves* generally, and the expanded posterior portion of the proximal phalanx of the index finger is entire, and not perforated as we find it in many of the *Laridæ*. The distal joint of this digit is long and slender, being once semibarbed near its lip, the projection standing out from its posterior angle. Long and spine-like, the free joint of medius is seen to be proportionately more slender in the Red-billed than it is in the Yellow-billed Tropic Bird. There do not appear to be any free terminal ungual joints at the ends of any of the fingers in these birds; and I have found no small sesamoidal bones either about the carpus or near the elbow joint.

The humerus alone of the bones of the pectoral limb is pneumatic.

Passing to the consideration of the *pelvic limb*, we find that the *femur* too, is generally a pneumatic bone, and is peculiar inasmuch at the foramina occur irregularly at the proximal end of the shaft either *in front* or *behind*, while in *P. æthereus* a single, circular pneumatic foramen is found in the majority of skeletons in the popliteal fossa near its center. For its proximal moiety, tibio-tarsus may likewise be hollow, and, in life, air gains access to its interior. In one of my specimens a small perforating foramen is seen between the low cnenial crests very near the summit of the bone. Below the point indicated, the remainder of the skeleton of the pelvic limb seems to be non-pneumatic.

The axis of the head of the femur makes a wide obtuse angle with the longitudinal axis of the shaft, and the pit for the insertion of the *ligamentum teres* is but very faintly marked upon the top of it. On the summit of the bone we find the usual articular surface, and above this the trochanterian crest is scarcely at all elevated. At the proximal end of the shaft, between the great trochanter and the *caput femoris*, a very appreciable fossa exists, and immediately below this a very distinct tubercle presents itself in a great many specimens especially of *Phaëthon æthereus*. It at once reminds one of the *trochanter minor* of the mammalia, and no such a character is ever to be seen upon the femora of any of the other steganopodous birds judging from those before me, and I do not now recall ever having seen it upon the femur of any other existing or extinct bird. This character is but faintly seen in the U. S. National Museum specimen of the skeleton of *P. flavirostris* (No. 17841).

At the distal end of the femur the condyles are not very prominent, and the internal one is small. Nor is the rotular channel or the popliteal fossa deep, but on the contrary they are both shallower than in many other birds known to me. We find the shaft in *tibio-tarsus* to be straight and nearly cylindrical. Proximally, the low cnemial process rises but a little above the summit of the shaft, while anteriorly, below it, the pro- and ectocnemial ridges are but very inconspicuously developed. It is between these latter that the small pneumatic foramen usually is seen. Distally the usual characters of this bone are to be observed; the osseous span to confine tendons, at the antero-distal end of the shaft is present, and passes in a slightly oblique direction over the channel it bridges; the condyles, with their usual reniform contour, are well separated from each other, and the intercondyloid notch between them, is marked in front, but very shallow behind. In the *fibula* we see a very slender and rudimentary bone. Especially is this the case below the 'fibular ridge' on the side of the shaft of the bone it articulates with, for it is then reduced to little more than a flattened osseous hair, closely applied to tibio-tarsus, but apparently never actually anchyloses with it.

Phaethonidæ always possess a *patella* in front of the knee-joint, and it is of an elongated form, being flat behind and convex in front, where it is distinctly marked in the transverse direction by the groove for the tendon of the *ambiens* muscle.

Most remarkable of all the bones of the pelvic limb in *Phaëthon,* however, is its *tarso-metatarsus.* To describe this I select the left one from one of my skeletons of *P. æthereus.* The bone is oblong in outline; much flattened in the antero-posterior direction; and with its middle trochlear process but slightly lower on the shaft than the internal one, which latter in turn is but a little lower than the outermost one. On the summit, the shallow articular depressions for the condyles of the tibio-tarsus are separated by a rounded eminence in front. At the back of the shaft, in this region, we find the "hypotarsus" to consist simply of three vertical ridges,—a short, small middle one, with longer and stouter outer ones. Anteriorly, the shaft of the bone is deeply scooped out from above, downwards for nearly its entire length. On the outer side below, this channel terminates in an antero-posterior perforating foramen,— situated at a point a little above the notch dividing the mid- and outer trochlear processes. On the *inner* side below, there is a small, longitudinally-disposed groove that runs into the main excavation on this aspect of the shaft at about its middle. This smaller groove also terminates below in an antero-posterior perforating foramen,— situated at a point a little above the notch dividing the mid- and *inner* trochlear processes. Thus we see in *P. æthereus,* there are *two* antero-posterior perforating foramina at the distal extremity of its tarso-metatarsus; —a very rare condition in existing birds, and even *absent* in *P. flavirostris*, where only the usual *outer* foramen seems to be present.

At the back of the shaft there is a low median ridge running down from the lowermost point of the hypotarsus to bifurcate below. One limb is lost on the posterior surface of the mid-trochlear process, the other on the outer one, while between them occurs the outer of the two perforating foramina just described above. Upon either side of this ridge, the shaft upon this aspect is also grooved in the longitudinal direction, but not so deeply as it is in front. Placed side by side in the anterior groove of the bone, just below the head, we find a pair of perforating foramina. They make their exit one upon either side of the lower part of the hypotarsus behind; each one lying in a postero-longitudinal groove, to which mention has just been made in the last paragraph. The sides of the shaft of this bone of the leg are more or less flattened, and the tubercle for the insertion of the *tibialis anticus*, is very small. The *first metatarsal* is free, being long and flake-like, and articulates by its entire outer margin, with the postero-internal edge of the shaft of the tarsometatarsus. *Pes* has what is usually termed the normal arrangement and number of joints to the several toes, *i. e.*, 2, 3, 4 and 5 joints, to the hallux, second, third and fourth digits respectively. Exceedingly slender and long, the basal joint of hallux is tipped off with a small, slightly curved ungual phalanx. The terminal phalanges of the three anterior toes are relatively much stouter, thicker, but exhibit about the same proportionate amount of curvature. With respect to the shafts of the intermediate joints, it is to be noted that they are long, slender, and exhibit but very little curving; while the articular ends of these bones are but very slightly enlarged. Indeed, the skeleton of the foot in the *Phaëthonidæ* is in reality delicately constructed.

TABLE.

Toes and their joints.		*P. flavirostris.* Measurements in mm.	Remarks.
Hallux or First Toe.	Basal joint..........	11	From this it will be seen that the length of the skeleton of the middle toe is about ⅗ the length of the tibio-tarsus. On the other hand it is longer than either the femur or the tarso-metatarsus.
	Ungual "	4	
Second or Inner Toe.	Basal "	15	
	Second "	12	
	Ungual "	5	
Third or Middle Toe.	Basal "	12	
	Second "	11	
	Third "	10	
	Ungual "	5.1	
Fourth or Outer Toe.	Basal "	10	
	Second "	8	
	Third "	8	
	Fourth "	8.5	
	Ungual "	4	

A proportionate increase in their length and caliber seems to be the only important difference that distinguishes the skeletal toe-joints of *P. æthereus* from the corresponding bones in *P. flavirostris.* To show the relative lengths of the phalanges in the last named species, see the above table, in which the measurements are given in millimeters.

Beyond the patella, already described above, I find no other sesamoids associated with the bones of the pelvic limb in the *Phaëthontidæ.*

Osteology of the Sulidæ.[8]

(See Plates XXII. and XXIII., Figs. 7–12.)

Of the Skull.—*Sula bassaua* has a skull that averages in the adult about 186 mm. in length; whereas in *Sula piscator* 129 mm. is the average length of the skull in the adult. Between these extremes we find the other species to fall, and a simliar variation is size is, of course, applicable to the remainder of the skeleton in these different specific forms of the *Sulidæ.* Apart from this, the characters presented in the skeletons of these birds in the main agree very well indeed, though differences do exist, and these stamp the skeleton of each species with an individuality peculiarly its own. The more important of these differences will be noted as we proceed. (See Plates XXII., XXIII., Figs. 7–11.)

In form, the superior osseous mandible is flat upon its under side with cultrate tomia, while superiorly it is convex from side to side, and tapers from base to apex gradually to a point, being a little decurved near the extremity. Sometimes we find it pierced by a foramen on this upper side, which leads to its hollow interior, but *Sula* is without nostrils, though did they exist, their position would perhaps be indicated by the posterior end of the longitudinal furrow that marks the mandible upon its lateral aspect.[9]

An osseous, thoroughly adherent crust, appears to overlay the greater part of the superior surface, the only smooth place being a small area in front of the craniofacial hinge, and even this is absent in *Sula piscator* and other species. Its entire surface is marked all over by an exquisite anastomosing venation, the ramifications

[8] Besides some four fossil forms, Dr. R. Bowdler Sharpe in his recent *Hand List of Birds*, recognizes the following species of the genus *Sula*, in which are included all the birds of this group at present known to ornithologists :—viz : *S. bassana*, *S. serrator*, *S. capensis*, *S. cyanops*, *S. abboti*, *S. piscatrix*, *S. websteri*, *S. variegata*, *S. nebouxi*, *S. sula* and *S. brewsteri*. In the A. O. U. "Check-List" we also find *S. gossi*, which may correspond with one of the species above enumerated, as *S. nebouxi*, or *S. websteri*.

[9] In my memoir entitled "Observations upon the Osteology of the Orders Tubinares and Steganopodes (Proc. U. S. Nat. Mus. Vol., XI., 1888, pp. 253–315), I give figures of all the principal bones of the skeleton of *Sula bassana*, drawn by me, natural size, direct from the specimens. These will not be reproduced here, while the osteology of other species of Gannets will be illustrated in the plates of the present memoir, as *S. gossi* and *S. brewsteri*.

starting, in some instances, from minute foramina found upon its surface. This venation is but feebly marked in *S. piscator*.

A *lacrymal* is a free bone, articulating with a roughened facet of some extent beneath the antero-external angle of the frontal above, and by a smooth, gliding facet on the upper side of the maxillary, which latter bone is thickened in a perpendicular direction and otherwise enlarged in order to offer it the proper amount of surface. As for the bone itself, it is of rather a columnar form, with the exception of its extended anterior margin, which is roundly notched and shows on its inner side the large pneumatic opening leading to its hollow interior. In *S. cyanops* this notch is extended as a groove entirely across the outer face of the bone, and the pneumatic foramen is seen in this groove.

In Gannets there exists, projecting horizontally from the outer margin of the frontal bone, on either side, from its "prefrontal process," a few millimeters posterior to the fronto-lacrymal suture, a small rounded ledge of membrano-cartilage, which reminds one of the horizontal portion of the true lacrymal bone in certain gallinaceous birds, as the *Perdicinæ*, for example. This feature has been studied by me in *Sula brewsteri* and *S. gossi*, recently killed specimens for which I am indebted to Mr. E. J. Reed of Guaymas, Mexico, who kindly collected them for me. This membrano-cartilaginous process probably never ossifies in the *Sulidæ*.

In the adult bird it is impossible to distinguish the exact position, or any of the borders, of the nasal bone.

The maxillo-jugal bar shows very plainly the suture between the jugal and quadrato-jugal; the latter is much smaller than the other portion, and shows a strong peg-like process upon the inner aspect of its posterior end, which is about at right angles to the axis of the bone. It fits in the deep conical socket on the side of the quadrate. Beyond its enlargement for the lacrymal the maxillary is a thin, horizontal plate of bone, anchylosed in the usual way at its anterior end. Here it really enters into the apparatus of the cranio-facial hinge. An ossicle having the appearance of a process pointing backward and apparently coming from the premaxillary is seen over this horizontal plate of the maxillary on either side. Professor Parker found this condition present also in another species of *Sula*, and this eminent anatomist apparently describes this ossicle as a "post-maxillary" for those birds. Either rudimentary or better developed, it is probably present in one form or another in all of the *Sulidæ*.

The interorbital septum, which is a thin, smooth plate, shows considerable of a fenestra near its middle, and a few such openings of a very much smaller size pierce its posterior wall in *S. bassana*.

The orbital cavity itself in Gannets is very deep, the eaves of its roof almost overhanging the jugal bar beneath. Its superior periphery is smooth and rounded. All in front of the rhinal chamber is filled in by the spongy mass formed by the united maxillo-palatines. The hinder portions of these bones are, however, still distinct in *S. bassana*, and they have all the appearance of these elements as they are found in birds which possess them as concavo-convex plates facing outward.

The rostrum of the sphenoid is a hollow subcylindrical tube, united above with the interorbital septum. As we proceed anteriorly it becomes more flattened from side to side, and gradually rises upward. At a point about half way between the palatines and cranio-facial hinge it terminates in a process directed forward; above this is the sharpened ethmoidal margin, nearly perpendicular to the long axis of the skull. Osseous wings to the ethmoid never develop in *Sula*, not even rudimentary traces of them being seen at their customary sites.

The cranio-facial hinge is exceedingly perfect in its construction, being composed of a thin plate of bone occupying the full width of the skull; the bones both above and below are separated from each other by a small interval for the entire length of the transverse line constituting the hinge. The part played in the mechanism by the maxillaries has already been described above.

We find the sphenotic process to be more or less bifid and jutting directly out from the side of the skull; on the other hand, the mastoidal process is a crest of bone curling forward. Between these two the very wide crotophyte valley is seen.

The quadrate is a large, massive bone, with its mastoidal head composed of two prominent ellipsoidal trochleæ, separated from each other by an intervening notch. Below these the shaft is seen to be rather compressed in an antero-posterior direction, and supports in front at its lower half an unusually formed orbital process. This is a thin, triangular plate of bone placed in the vertical plane, and with its apex directed forward. The pneumatic foramen of the quadrate usually occurs on the posterior aspect of the shaft in most birds, but here it is situated to the inner and lower side of this orbital process. In *Sula cyanops* I find two others on the anterior aspect of the bone, one near each articular process.

The pit for the quadrato-jugal is cylindrical and deep, and a perforation at its bottom may lead into the hollow of the bone. On the posterior aspect of the quadrate we find an irregular facet for the mandible; it looks directly to the rear and stands at the head of a longitudinal and deep groove which is found between two similarly placed facets on the foot of the bone.

Each pterygoid is a trihedral and compressed bone with prominent borders.

Regarding this skull from a superior view, we see in it a foramen in the superior mandible, near the site of the narial opening of the majority of other birds. From this aspect we also have a good view of the wonderfully perfect cranio-facial hinge of this bird.

Posterior to this is a broad, smooth area, very slightly convex, and showing in some species numerous venations like those on the bill of *S. cyanosis*. This surface extends from the cranio-facial hinge to the anterior border of the crotaphyte fossæ, while laterally it is bounded by the margins of the orbits.

This view also shows the extent and form of these crotaphyte fossæ, and how they are separated from each other in the median line, simply by an extension backward of a very narrow strip of the general surface that lies beyond them. They merge with each other in some specimens of *S. piscator*. They are bounded behind by conspicuous and sharpened crests that curl slightly forward, and are best marked laterally, becoming very low as they near the upper part of the supra-occipital prominence.

The under view of the skull reveals a number of interesting points. We find that the anterior portions of the palatines are parallel to each other, separated by a median cleft of a width equal to either one of them, and which becomes pointed behind.

Their anterior ends do not merge into the premaxillary beyond until they are well past the points where the maxillaries are inserted. These anterior portions are thin, horizontal plates, being directly continuous with the horizontal and fused palatine bodies behind. This latter portion shows a small median carination just in front of the united heads, and the postero-external angles are rather sharp, being pointed directly backward.

Anteriorly, the pterygoidal heads meet each other and the fused palatines, the three forming a groove on their upper sides for the rostrum. At their outer ends each pterygoid offers a shallow cup to form the usual articulation with the quadrate of the corresponding side.

Professor Parker found that "in *Sula alba* the basitemporals are as little developed as in the *Dromæidæ*, less than in any other carinate bird. Behind each moiety there is a large oval opening, not far in front of the occipital condyle; this exposes the loose diploæ within. The small Eustachian tubes open at a little distance from each other, in a wide, shallow fossa, on the part where the three elements of the parasphenoid meet." The description of these details agrees with the skull of the specimen before me. Professor Parker, however, was fortunate in having the skeleton of the ear-parts in his specimen, and, of them, he says that "in *Sula alba*, the columella auris is very long and bent. It has a small, cartilaginous, extra-supra-stapedial process, and a long, attenuated stylohyal."

On either side, the entrance to the middle ear in *Sula bassana*, as in others of the same genus, is shallow, and it is situated quite internal to the quadrate bone, while immediately mesiad to it there is a pit of great depth, with its aperture looking downwards, and its base in the vault of the cranium, which seems designed for muscular lodgment; the positions of the usual foramina about it are peculiar, and extremely interesting in these birds.

The bony wings that shield the entrance to the ears are large and tilted up behind. Each one shows the double facet for the mastoidal head of quadrate, the outer one having its inner margin encroached upon by the pit described above.

The postero-internal angle of either of these wings is connected with the side of the elevated basi-temporal region by a bony bar. This condition can best be seen from a posterior view. When speaking of the orbital cavity I neglected to mention that the upper part of the septum is longitudinally marked, as in most birds, by an open, single groove for the passage of the olfactory nerve to the rhinal space beyond. The exit for it from the brain-case is very small, indeed, and occasionally, in *S. bassana*, on one side, the bone spreads over it, rendering the nerve track, for a fraction of the initial part of its course, tubular.

The brain-box itself is capacious and notable for its great width over its compression in the vertical direction. Its anterior wall looks directly downward and forward, making an angle of about 45 degrees with the horizontal palatine bodies. Seen from behind, the skull shows, above, the extent to which the crotaphyte fossæ approach each other in the median line and the crest that divides them from the occipital area. This latter has the usual form seen among these cormorant-like birds, constituting an arch over the foramen magnum, which occupies the center of a concavity below it. The supra-occipital prominence is here distinguished by a low, smooth median ridge, which traverses this dome-like elevation from the inter-crotaphyte line to the superior periphery of the foramen magnum.

The plane of this latter aperture is about perpendicular to the plane of the basis cranii. In outline the foramen is broadly elliptical, with the short axis transverse. At its lower margin we see a large ellipsoidal condyle, with its short axis at right angles with that of the foramen. Below this again are the oval openings in the basi-temporal, spoken of by Parker, with the prominent descending processes of this region flanking them on either side.

In form, the inferior *mandible* is spear-shaped, its sides tapering gradually to a sharpened apex. These latter, for the outer aspects of their anterior two thirds, show the same character of venated surface as I described for the superior mandible. Posterior to this, however, as well as the inner ramal aspect, the bone is smooth, having the same appearance as in most birds.

The symphysis is short and develops a spine behind, which points directly backward and is in every respect similar to the process in the same place, between the sides of the lower jaw, in Herons and Albatrosses. Each ramus of this mandible is very thick from side to side, but these parts are hollow, and the bone as a whole, is very light, owing to the high state of pneumaticity it enjoys.

The principal foramina for the entrance of air to its interior are four in number, two on either limb, one being to the mesial side of the articular cup, and another larger, longitudinally piaced, elliptical one just beyond this concavity on the inner aspect of the ramus near its upper border. The superior side of an articular end has a deep excavation at its center upon which the facets for the quadrate do not encroach, so that, when the jaw is articulated, this pit comes opposite the notch between the trochleæ of the mandibular foot of the quadrate, creating an irregular hollow space there between the bones of no inconsiderable size. When the quadrate thus covers it there are two entrances that are left open, one in front and one behind, close to the pneumatic foramen.

The mandibular angles are truncate, very nearly perpendicularly so, their surfaces being concave and very broadly luniform in outline (Plate XXII., Fig. 7).

Commencing just in front of an articular cup, we find the superior border of the ramus to be rather wide and rounded as far as the meeting with the dentary This portion presents near its middle a double coronoid process, one being in front of the other. The dentary portion of their border has an outer cultrate edge and an inner and somewhat lower rounded one.

The outer edge goes to the anterior apex of the symphysis, the inner one to the hinder termination of the same, while between the two a nearly horizontal surface is contained, which gradually becomes narrower as we proceed in the forward direction.

The lower borders of the mandible are rounded for their entire extent, being produced beneath the articular cups and continuous with the inner boundary of either truncate angular extremity.

We find that the usual bones which surround the true ramal vacuity on the side of the mandible in many birds, here interlock with each other so as to completely fill the fenestra in, but in rather an unusual way, and apparently, for a definite purpose; for each ramus presents, both on its inner and outer side, an oblique slit, these slits being opposite each other and with their anterior ends in the superior border. It is evident that this otherwise thick jaw is much weakened at these points in each ramus, and this occurs just posterior to the hinder termination of the horny sheath of the lower beak. In other words, the hinder moieties of the mandible are attached to the anterior or dentary portion by thin plates of bone, consisting principally of the splenial elements, and are capable of being bent outward, which, in the recent specimen can, owing to the way the quadrates are attached, be effected to a considerable degree. Now in life these oblique slits have their anterior ends come opposite the thin anterior insertions of the maxillaries, and these latter are just beneath the very mobile cranio-facial hinge, so that the whole apparatus is admirably arranged to permit an increase in size of the fore part of the buccal cavity when a Gannet swallows the fish that constitutes its food, and which its beak is so well fitted otherwise to capture. Moreover, this possible increase in caliber takes place in that portion of the digestive tract where it is most needed, or where the bony walls of the mouth would prevent the admission of a very large morsel, unless some such mechanism existed, — that is, at the very entrance of the buccal cavity, and just posterior to the more horny thecæ of the beak. In Gannets, however, this mobility is, to some extent, restricted by the integumental sheath of the beak.

Sulidæ have a wonderfully pneumatic skeleton, the entire structure enjoying that condition, save the ribs; all the caudal vertebræ (with the occasional exception of the anterior one)'; and, finally, none of the bones of the pelvic limb are pneumatic below the femur. The entire skeleton of the wing is perfectly so.

In a specimen of *Sula gossi* before me, *nine* or *ten* large *sclerotal plates* ossify in either eyeball, and these overlap each other much as we find they do in other birds. All the *tracheal rings* ossify quite perfectly, as do the *bronchial semirings* as they approach the lungs. These rings look like little, narrow, bony, double-overlapped straps, as they are arranged *in situ* to form the somewhat antero-posteriorly compressed windpipe. The usual bones of the *superior larynx* also ossify, and in the *syringeal portion* of the tube we find strong osseous arcades overarching the commencement of either bronchial tube, and parallel to them below, in the median line, the dividing *pessulus* is also in bone.

Anatomists have long known that the *hyoidean apparatus* as found in the *Sulidæ* is invariably a very much aborted affair. The only parts of it that ossify are, first, a little irregular piece which represents the *first basibranchial;* and second, articulating with this behind, are two simple curved rods of bone, which are the *cerato-branchials* of the thyro-hyals. Beyond these, no part of the tongue of a Gannet ever appears to ossify. It is hardly necessary to say that such parts of the skeleton as the sclerotal plates, the tongue, or rings of the trachea, or much less certain sesamoids we will hereafter be called upon to describe, are ever pneumatic.

Of the Remainder of the Skeleton of the Trunk in the Sulidæ. (See Plate XXIII., Fig. 12.)

In the common Gannet there are twenty-one free vertebræ in the spinal column before we meet the one that first anchyloses to form, with the assistance of the fourteen succeeding ones, a sacrum for the pelvic bones. Then follow seven more free ones, devoted to the movable part of the tail. Finally, we have a long pygostyle that probably contains at least six more. Owing to the lengthening behind of its pelvic bones, the sacrum contains sixteen vertebræ in *Sula cyanops*, and that species has but six free caudal ones plus the pygostyle.

The sixteenth, seventeenth and eighteenth vertebræ support each a pair of free ribs; the next three belong to the dorsal series, and all have true vertebral ribs articulating with costal ribs from the sternum. This is also the case with the first three pairs that spring from the pelvic sacrum. The ribs on the sixteenth vertebra are exceedingly rudimentary, and the last pair of "floating" costal ribs have no corresponding pair of vertebral ones above them.

In mid-series these ribs support epipleural appendages, attached in the usual way to their posterior borders. (They may be anchylosed or free.) As I have already stated above, they are completely non-pneumatic.

The neural canal is notable for being nearly cylindrical throughout the first twenty-one vertebræ. It is only at the region of the enlargement for the brachial plexus that it is rather compressed in the vertical direction.

The atlas has a minute perforation in its cup, and its neural arch is strikingly broad and deep. The axis vertebra possesses a stumpy neural spine, and its hypapophysis, directed somewhat backward, is very prominent.

The odontoid peg is comparatively small and nearly sessile with the centrum, the latter presenting a concave face below it.

From the third to the fourteenth vertebra, inclusive, the neural spine is a very inconspicuous character, while from this on it gradually makes its appearance, increasing in size until we have the usual quadrate, longitudinal plate of the dorsal series.

The third and fourth vertebræ have each a prominent hypapophysis like the one on the axis, but in the fifth this feature nearly entirely disappears.

The sixth vertebra is faintly marked by the carotid canal; this gradually becomes more and more tubular in the seventh and eighth, while in the ninth to the thirteenth inclusive it is a closed cylindrical canal of a caliber somewhat less than the neural canal canal above it. It disappears entirely from the fourteenth vertebra.

The lateral canals extend from the third vertebra to the fifteenth, inclusive; they are short in any of the segments, and their posterior apertures are far larger than their anterior ones.

At the commencement of the cervical series the parial parapophyses are short and not particularly well developed. They project backward from the inferior walls of the lateral canals, but as the carotid canal begins to develop, these processes withdraw from the former positions, move gradually lower down beneath the centrum, and at the same time increase in length and importance, so that in those vertebræ where the carotid canal exists, they project from its postero-inferior border directly backward as parallel and not far separated spines.

The post-zygapophyses do not appear as divergent limbs until we find them so in the eighth vertebra; in all the cervical segments anterior to this one the facets are situated on the inferior aspect of the tuberous hinder end of the neural arch at its lateral angles.

Metapophyses are seen on the ninth vertebra, but gradually disappear, to be entirely absent in the fourteenth or fifteenth.

The transverse processes in the dorsal region are broad, flat, and horizontal, being directed more and more to the rear as we approach the pelvis. The plates of the neural spines above do not meet each other when the column is articulated, and there is an entire absence of all interlacing, ossified tendons or metapophyses in this region. In fact, all the vertebræ have a very clean-cut, non-angular appearance, with the majority of projecting borders rounded.

The articular ends of the centra are constructed upon the "heterocœlous" type; the anterior faces in the ultimate cervicals and leading dorsals being notably wide and shallow, and often riddled with foramina.

The pygostyle and the free caudal vertebræ will be spoken of after the pelvis has been described; in the meantime we will turn our attention for a few moments to the description of the sternum and pectoral arch.

The Sternum.—This bone in the Gannets has a very peculiar form. A pectoral aspect of the bone shows that the body has an oblong figure or outline, with the average width nearly equal to half the length. Beyond the true sternal body the anterior portion projects as a massive promontory, and a large part of the carina is beyond this again.

The anterior moiety of the bone is convex upon the dorsal side, and correspondingly concave on the ventral aspect. Behind, the body is so flattened out in *S. bassana* as to be nearly horizontal. The costal borders look outward and slightly upward, and each usually possesses six moderately well-developed facets for the costal ribs. In a specimen of *S. bassana*, however (No. 18045 U. S. Nat. Mus.), and in one of *S. piscator* (No. 18739, U. S. Nat. Mus.), I find but *five* of these facets upon either costal border. There are no pneumatic foramina in the elongated and shallow intervals between them.

The principal orifices of this character consist in a diffuse group on the superior aspect of the anterior projecting part, within the general concavity of the bone.

Either costal process gracefully rises from its base as a laminated and prominent horn, curving in the anterior direction.

The posterior moieties of the lateral borders are somewhat rounded and extend almost directly backward over the lateral processes behind.

These postero-external xiphoidal processes are very long and wide, being rounded off at their extremities and directed a little outward. They are narrowest in *S. brewsteri*, more flaring in *S. gossi*, and very wide in *S. cyanops*.

They are created by this hinder portion of the bone being so profoundly one-notched that a general concave margin has resulted, with simply a median papilliform process remaining. Even this latter is frequently altogether absent in *S. gossi*, converting the posterior sternal border in this species into one long, well-marked concavity.

The carina juts out very prominently in front of the bone; its anterior angle is concave from above downward, and develops a large facet for the furcula, which in life articulates with it. Above this the border is again concave and sharp, while still above this there is a compressed process that represents the manubrium. This is the case in *S. bassana* only, for in the sternum of no other Gannet before us is there the slightest semblance of such a process as the manubrium.

The lower border of the keel is straight and in the horizontal plane, being capped off with a spreading rim. This border merges into the surface of the body of the bone before it half way reaches the xiphoidal notch.

The sides of the keel are smooth, and neither it nor the under side of the sternal body show in this specimen any of the muscular lines usually present in most birds.

A broad median notch, concave from side to side, convex from before backward, lies between the lofty superior portions of the coracoidal grooves. These latter meet in front of it, while behind, its surface becomes directly continuous with the general surface of the upper side of the body, and that where the group of pneumatic foramina are found.

A coracoidal groove looks forward and outward for its upper portion, directly upward for its lower, and extends rather less than half way between the base of the costal process and the median line. It consists of two portions which are directly continuous with each other. The lower one is a shelf-like projection with a convex border forward and its articular surface in the horizontal plane. Immediately above this rises a much broader surface, though not so long, which is decidedly convex from above downward. This portion of the facet for the coracoid is considerably higher than the plane in which the borders of the body of the bone are found. It faces forward and outward, and has one regular convexity as its limiting margin above. Between the point of its outer termination and the apex of the corresponding costal process, the border is one sweeping concavity.

This form of sternum is more or less peculiar to the *Sulidæ*, and it departs in a number of points from the form of the sternum of the Cormorants and of the Pelicans. Comparatively, the bone is not so long in *Sula gossi* as it is in *S. bassana*, *S. brewsteri* and other species. Still the *general pattern* of the sternum is much the same throughout the *Sulidæ*. If we overlook the crossing of the coracoidal grooves in the sternum of *Phaëthon æthereus*, and its having a manubrium, there is a great deal in the bone to remind us of the sternum of *Sula gossi*—and, in fact, there are more steganopodous characters in the sternum of the Tropic Bird than there are of any other avian group with which I am at present acquainted.

Of the Shoulder-girdle.—(Plate XXIII., Fig. 12.) This part of the skeleton is, like so much of the rest of it, thoroughly pneumatic, the foramina occurring at their usual sites.

The clavicles form a broad U-shaped arch, being completely united below, where, at the median point beneath, they support an extensive facet for articulation with the carinal angle of the sternum. This does away with any such thing as a hypocleidium proper, notwithstanding the fact that the bone projects slightly over this facet.

The clavicular limbs are compressed from side to side, broader above than below, with their anterior and posterior borders rounded off.

A clavicular head is also compressed in the same manner as its shaft, and tapers off as a pointed process.

The most striking feature of this part of the bone is, however, the extraordinary facet it supports to articulate with the coracoid. Either one of these is situated at its outer side, upon a promontory of bone which is found there, the latter being of a proper form to receive it. The facet is of an elliptical outline, placed vertically, and facing directly backward. Something of a notch is found between it and the clavicular head, in which occurs a number of the principal pneumatic foramina of the furcula. On the anterior surface, just below the summit of a *coracoid*, we find a distinct elliptical facet for articulation with a similar one just described for the fourchette. Between this and the ear-shaped glenoid facet a considerable valley is found. On the opposite side of the coracoidal head we find a group of pneumatic foramina, and below these a peculiarly formed scapular process, a spine-like apophysis, which rather gracefully curls upward and then toward the shaft of the bone. This latter portion of the bone is subcylindrical and smooth, dilating below into a transverse fan-shaped sternal extremity.

A *scapula* offers but a very small portion of the articular surface for the glenoid cavity ; not more than an eighth of it in all the specimens examined by me. The head of the bone then reaches forward and inward, but only the outer two thirds of this makes an indifferent articulation with the narrow and roughened border of the scapular process of the coracoid. The shaft of the bone is quite stout behind this and somewhat compressed in the vertical direction, while posteriorly it flattens out into a broad paddle-shaped extremity that finally tapers to a point behind.

Even more than it is in the case of the sternum, the bones of the shoulder-girdle in all the species of the *Sulidæ* at my hand are, apart from their specific variance in size, almost identically alike in each and every one of their corresponding characters. As for the bones of the shoulder-girdle in the *Phaëthonidæ*, we may say here, by way of comparison, that it is only in the scapula where we see the characters which more or less resemble the corresponding ones as we find them in the scapulæ of the *Sulidæ*. Neither the *os furcula* nor a coracoid of a gannet or booby bear any special resemblance to those bones as they exist in the tropic birds.

Of the Pelvis and Caudal Vertebræ.—The first vertebra that anchyloses with the pelvic sacrum anteriorly projects entirely beyond the iliac bones. Its centrum, in common with the next three that follow it, is much compressed from side to side, and its neural spine is continuous with the common neural ridge above the succeeding segments.

The first five vertebræ that lie beneath the ilia throw out their apophyses in the usual way for their support; the last two of this series meet the iliac margins. Here the neural canal and centra are large, in order to afford room for the increase in size of the cord where the sacral plexus is thrown off.

The twenty-eighth and twenty-ninth vertebræ have their processes thrown directly upward, so that they are scarcely visible upon direct ventral aspect.

In the thirtieth vertebra they are powerfully developed and extend directly across the basin to abut by anchylosis against the pelvic walls immediately behind the cotyloid cavity on either side. From this point the centra of the so-called uro-sacral vertebræ taper quite rapidly in size to the ultimate one, which, in *S. bassana*, is enlarged and exhibits a big facet on its posterior aspect, intended for the first free caudal. In *S. piscator* this enlargement is not evident.

The extremities of their diapophyses anchylose in a very thorough manner with the inner iliac margins, and a lateral view shows their sides to be riddled with pneumatic foramina between these processes.

Viewing this pelvis from above, we notice that the entire inner margins of the iliac bones have merged into and completely anchylosed with the sacrum. This converts the ilio-neural grooves into ilio-neural canals and gives the bone a very compact appearance. The anterior margins of the ilia are rounded, and are set off with rather a deep and raised emargination in *S. bassana*, which is feebly marked in *S. piscator* and other species.

The post- and pre-acetabular surfaces are about equal in the extent of their superficial areas, except in *Sula cyanops*, where the postacetabular area is the more extensive.

The anterior iliac surfaces are concave on either side, and each faces upward and outward to about an equal degree. *Sula piscator* here offers another exception, and in this species the pelvis is comparatively shorter, as well as broader and flatter than it is in other species of Gannets.

Elevated above these anterior iliac concavities we find the postacetabular area to be nearly horizontal. Large elliptical foramina are found between the apophyses of the last three or four uro-sacrals, and these latter, likewise, develop quite a prominent neural crest.

Upon the lateral aspect of this pelvis we find a very large cotyloid ring, the inner margin of which is fully equal in size to the outer. A moderately sized antitrochanter occupies its usual site, with its articular surface directed downward, forward and outward.

Behind this occurs an enormous elliptical ischiadic foramen, that occupies nearly all of this post-acetabular lateral aspect. Through the fenestra thus formed we are enabled to get a good lateral view of the uro-sacral vertebræ and the extensive pneumatic condition they enjoy.

The lower margin of the ilium is sharp and convex ; it forms the superior boundary to a long, narrow, obturator space, which opens freely into the rather small obturator foramen.

A pro-pubis does not develop in the Gannets, while the post-pubis is, for the most of its extent, fragile and slender. It begins to increase in size just before arriving at a point opposite the end of the ischium. At this point it offers a small facet on its upper margin for the ischiadic postero-inferior angle, and the two bones are in contact here during life. The post-pubis, retaining its increase in size, then curves inward toward the fellow of the opposite side, to terminate in a cartilaginous tip.

The posterior border of this lateral aspect shows a well-marked ilio-ischiadic notch at about the middle of its extent. This character is best marked in *S. cyanops* and *S. gossi*, being much shallower in other species, especially in *S. piscator*. The outer side of the bone between it and the ischiadic foramen is directed upward as well as outward.

As has already been mentioned above, there are usually *seven* free vertebræ plus a large pygostyle in the skeleton of the tail of most Gannets and Boobies, but an exception is noted in the case of *Sula cyanops*, in which species I count in the specimen before me, only *six* and the pygostyle. The characters of these vertebræ may be well studied in the skeleton of the tail in *Sula brewsteri*. What first strikes one upon glancing at this part of the osseous system of any Gannet is its comparative massiveness, the great size of the individual vertebræ, and the large pygostyle. The neural spines however, are short and stumpy; in *Sula bassana* they are occasionally bifid anteriorly. The neural arches beneath them close over the spinal canal for the entire length of the series, and the latter, for a short distance, is seen to perforate the pygostyle. The transverse processes are thick and strong, being very wide-spreading, especially in the case of the ultimate and penultimate free ones. From four to five of the last ones usually develop hæmal spines. These become larger as we approach the pygostyle, the first vertebra of which also has one, it being bifid, and hooking forward, as do those on the caudals in front of it. The interarticular facet on the faces of the centra are nearly flat, showing barely any concavity or convexity.

The *pygostyle* appears to be composed of about six vertebræ, of which the three anterior ones can be quite easily made out. It has a very unusual form in this bird, being very long and subconical, with sharp superior border and rather decurved apex. Below, it is broad and somewhat convex. Viewing it from in front we notice that it has all the elements present, though in very rudimentary state, of one of the caudal vertebræ, including the large, prominent and anchylosed hæmal spine just mentioned.

The Appendicular Skeleton.

The Pectoral Limb. — We find the humerus in *Sula bassana* to be somewhat longer than the radius and ulna in this limb, but we shall see later on that this varies greatly in the other species. I will write out here first an account of the appendicular skeleton of *Sula bassana*, and close with the differences exemplified on the part of the other Gannets and Boobies we have under consideration. In this humerus the ulnar crest is prominent and projecting, though rather inclined to retreat from the elongated and shallow pneumatic fossa that arches over it, as in many other water birds. The radial crest is reduced to a long, low, inconspicuous ridge, and, in fact, this proximal end of the humerus, as a whole, merges into the shaft so gradually from both sides, and its being so narrow withal, that we are rather impressed with its lack of strength and an absence of a certain robustness so characteristic of the bone in other birds of equal size and that lead a similar life. This in no way applies, however, to the shaft itself, for this subcylindrical and hollow, bony tube, with its double sigmoidal curve, carries with it the very elements of strength and power.

Its distal extremity lacks but little of being as wide as the widest part of the head of the bone. It is without an ecto-condyloid process, has the trochleæ very prominent, and presents for examination a deep fossa to the anconal side of the ulnar tubercle.

The shaft of *radius* for so long a one is unusually straight, and only a slight curve is noticed in the proximal moiety of the *ulna*.

In its continuity the former bone is subtrihedral in its form, with its pneumatic foramina situated beneath the transversely expanded portion of the distal end. Muscular lines mark this radial shaft along its inferior aspect.

For its distal moiety the shaft of ulna is nearly cylindrical in form, but this is gradually exchanged for the subtrihedral as we pass over the proximal half of the bone.

It presents for examination a double row of feebly marked papillæ for the quill-butts of the secondary feathers.

A long, shallow, though notable fossa is seen at the proximal and anconal side of the shaft, which terminates in a single pneumatic foramen just beyond the prominent cup-shaped articulation for the ulnar tubercle of the humerus.

Other pneumatic holes occur at the distal end of the ulna upon all sides, except the outer one. The olecranon, though large and rather tuberous, would not particularly attract our attention. A distinct canal upon the outer aspect of the distal end of the shaft for the passage of the tendons characterizes this bone. The articular surface shows nothing of special interest.

As usual, the carpal segments are but two in number — a *radiale* and an *ulnare*. They present the forms and facets common to these bones generally. Both are pneumatic and have large apertures for the admission of air to their hollow interiors.

The *carpo-metacarpus* also presents a number of those foramina at either of its extremities; the principal one, however, is found just below the trochlear surface formed by os magnum upon the anconal side of the bone. A notable process occurs immediately below it, as well as another group of these air-holes, in its outer aspect, near the short and inconspicuous first metacarpal.

The main shaft is straight and of good caliber; on the palmar side it is longitudinally grooved nearly its entire length for a tendon going to the fingers. This is best marked upon the distal moiety of the bone. The metacarpal of the middle digit is also straight for the major extent of its course; its extremities becoming enlarged in order to allow it to make the usual connections with the metacarpal index. It is rather slender and develops no special processes, as it sometimes does in other representatives of the class.

The expanded portion of the proximal joint of the index digit is not perforated, not even by the numerous pneumatic foramina which are irregularly scattered over its surface. Below it is produced as a notable process, and a process that is seen in some of the extinct birds, as, for instance, in *Ichthyornis*. The shaft of this phalanx is broad and flat anteriorly, and perfectly straight from above downward.

Equal to half the length of the carpo-metacarpus, the distal phalanx of the index digit is of a trihedral form, with an extensive excavation at the posterior aspect of its proximal end, which is continued in a lesser degree the entire length of the bone. It bears no claw below, but is finished off by a distinct little process.

The pollex phalanx has very much the same form as the one just described, but it lacks the longitudinal excavation down its posterior aspect. Both of the bones are pneumatic. Lastly, we have the smallest phalanx of all, belonging to the middle finger. This, as usual, is behind the broad proximal joint of the index, and not quite equal to half its hinder border in length.

Now the general characters of the bones of the pectoral limb are, in *Sula cyanops*, *S. piscator*, *S. gossi* and *S. brewsteri*, in the main about the same as they have just briefly been given for *Sula bassana*. We find differences, to be sure, but they are very slight. The humerus in *S. cyanops* closely resembles that bone in *S. bassana*, only it is considerably smaller in the first-named species. Occasionally about the proximal end of the carpo-metacarpus the position and size of the pneumatic openings may vary, but that is often seen to be the case in all large birds with highly pneumatic skeletons.

In *S. piscator* the olecranon fossa of the humerus is comparatively larger and with better defined borders than it has in *S. bassana*. This is likewise the case in *Sula gossi* and *S. brewsteri*, in both of which species that fossa is especially well marked. Beyond such trivial departures as these, we meet with little or nothing worthy of formal record. Individual specimens of the same species, however, vary a little; take, for example, the carpo-metacarpus. It is seen to be rather smaller than that of another specimen of the same species of *S. bassana* now at my hand for comparison.

Where remarkable differences do come in, is in the relative *lengths* of these bones when we come to compare them in one species with the corresponding bone in another. In speaking of *Sula bassana,* I said above that its humerus was *longer* than the radius or ulna; now this is not the case in other species of Gannets, as the subjoined table will plainly show.

MEASUREMENTS IN CENTIMETERS AND FRACTIONS.

Species.	Humerus.	Ulna.	Carpo-metacarpus.	Joints of Index Digit.
Sula bassana.	23.5	20.4	9.6	9.6
Sula cyanops.	19.3	20.7	8.8	8.1
Sula piscator.	17.1	18.4	7.2	6.9
Sula gossi.	16.2	17.3	7.6	6.9
Sula brewsteri.	18.4	19.8	8.1	7.6

Of the Pelvic Limb.—In comparison with the general size of *Sula bassana* the lower extremity is very short, though the bones composing its skeleton are none the less strong in consequence. In the *femur* we find the axis of the head and neck making an angle with the longitudinal axis of the shaft. The head is quite distinct, globular, and, as usual, excavated on top. Its surface is continual with the broad articular surface which occupies the entire summit of the bone. No trochanterian ridge rises above this latter, and, indeed, this character of the femur is but poorly developed.

A pneumatic foramen is always seen at its most common site, on the anterior aspect, just below the superior articular surface.

The shaft is cylindrical, roughened in some places by lines and diffuse tuberosities for muscular attachment, and is bent slightly to the front and somewhat to the inner side. At its distal extremity the condyles are fashioned after the usual pattern among birds, but all their characters in *Sula* present a sort of lack of strong development. The fibular cleft is but faintly marked, the intercondyloid notch or fossa is shallow, and the ridges in front much rounded and inconspicuous.

Something of the same condition is extended to the proximal end of the *tibiotarsus* of the leg, though not to such a marked degree. Here the cnemial process rises but slightly above the articular summit of the bone, and the pro- and ecto-cnemial ridges which descend below it soon merge into the shaft, and are, at the best not very prominently developed.

The shaft of this bone is straight and smooth and somewhat compressed throughout from before backward. It offers a long ridge to the fibula and is broad across where it is found. The distal extremity of the bone evinces more character than the proximal one. An oblique bridge, to confine the extensor tendons, is extended across the deep groove that contains them during life. Nearly parallel with each other, the condyles are wide apart, prominent and convex in front, to become suppressed and low and thin-crested behind.

The fibula has the usual form seen in birds, but is here particularly interesting from the fact that it does not anchylose with the shaft of the leg-bone until it arrives at the middle of its lower third, and even from this low point the remainder of the bone, including an oval "external malleolus," stands out quite prominently. This rare condition of things has been pointed out also by me as occurring in *Urinator lumme.*

Sula bassana has a long oval *patella,* obliquely marked across its anterior surface by a groove for the tendon of the ambiens muscle.

The *tarso-metatarsus* in *Sula* is strikingly large in its proportions when compared with the other bones of the limb. In length it is a little more than half as long as the tibiotarsus, but being wider and broader it appears much more massive. Its hypo-tarsus presents three short, longitudinal elevations of unequal sizes. These inclose two tubular passages for tendons, and are grooved themselves besides. In other specimens they are flat, and the two outer elevations may posteriorly meet, thus creating a vertical perforation rather than a groove. The back of the shaft is flat, but in front it is much scooped out above, where it shows two antero-posterior perforations.

At the distal extremity three large trochlear projections present themselves. They are separated from one another by wide clefts of about an equal depth. These trochleæ are placed nearly side by side, the middle one being the lowest down, the inner next, and the outer one the most elevated. Their median grooves are best marked behind, but in addition the internal trochlea presents a deep, vertical notch upon its outer aspect.

The usual arterial perforation pierces the bone above the cleft found between the outer and middle projections, a groove leading into it from above.

The accessory metatarsal is rather an elongated bone, swung in the usual way by ligaments to the lower part of the shaft.

The basal joint of the hallux, which it supports, is comparatively more slender for its length than the other joints of the foot.

For the three anterior toes these latter are, in number and arrangement, the same as in the vast majority of the class. They present all the characters usually attributed to the phalanges of the podal digits in birds, and are well proportioned, both as regards their relative calibers and lengths.

The pneumatic foramen in the femur of *S. cyanops* is usually very large, and comparatively small in my specimen of *S. piscator*. This also applies to *S. brewsteri*, but in *Sula gossi* it is notably very large again. The general characters of the femur are much alike in all typical Gannets.

The tibio-tarsus and fibula in *Sula cyanops* agree with those bones in *S. bassana*, as they practically do in other species. There is a difference seen in the degree of distinctness of the distal end of the fibula. The entire bone can easily be made out in all my specimens of *S. gossi*, and only, or less than, the distal fourth of it fuses with the tibio-tarsus in that species. The tibio-tarsal condyles are far apart in *S. piscator* and *S. gossi*, and in most birds of this family this character is more evident than it is in *S. bassana*. In this last-named species the tibio-tarsus and tarso-metatarsus are all non-pneumatic; I fail to find any pneumatic openings in the tibio-tarsus of *S. cyanops*, but the tarso-metatarsus of that species enjoys that condition to a very high degree, as numerous and large air-holes are found about the head of the bone. Another remarkable fact is that the tarso-metatarsus in *Sula cyanops* is rather larger than that bone in *Sula bassana*. It is very small in *S. piscator*, and in all considerable variation may exist in the hypotarsus, for the places where the tendons pass through may be either grooves or perforations. Whatever they are, however, they never exceed two in number. Below I give a table showing the comparative lengths of these bones in the species under consideration.

MEASUREMENTS IN CENTIMETERS AND FRACTIONS.

Species.	Femur.	Tibia.	Tarso-metatarsus.	Middle Anterior Toe.
Sula bassana.	7.4	10.9	6.1	
Sula cyanops.	6.4	9.9	6.5	
Sula piscator.	4.9	6.9	3.8	
Sula gossi.	5.4	7.9	4.9	7.9
Sula brewsteri.	5.9	9.1	5.7	8.3

From this study it is hardly necessary to add that the skeleton of the pectoral and pelvic limbs of the *Sulidæ* is entirely different from the corresponding parts and bones in the *Phaëthonidæ*.

ANHINGIDÆ.

Osteology of Anhinga anhinga.

As will be seen by my list of material given above, I have, at the present writing, but a single skeleton of this family of birds, before me for examination. It is complete, however, and there are at hand the accounts of the osteology of *Plotus* by other authors. Doctor R. Bowdler Sharpe in his recent *Hand List of Birds*

(1899) retains all the Anhingas in the family *Plotidæ*, and, in addition to two fossil forms, recognizes our existing species, viz: *P. rufus*, *P. melanogaster*, *P. novæ-hollandiæ*, and *P. anhinga*. The *Anhinga anhinga* is the sole representative of this family in the United States. A peculiarity of the skeleton of *Anhinga* is, it is almost completely non-pneumatic. It is only into the base of the cranium and the articular ends of the mandible that air gains access through minute foramina occupying the usual sites.

Of the Skull.—This bird has a very perfect "cranio-facial hinge," and measuring each way from the center of it we find the superior mandible to be about 1.5 cm. longer than the cranium. In form the superior mandible is long, narrow and spear-shaped, being drawn out to a sharp point. It is nearly straight. Beneath, it is flat with cultrate tomia. The culmen is rounded off, and the nasals have so fused with the surrounding bones of the face that most of the sutural lines cannot be distinguished in the adult. Where the external nostrils would naturally occur, there are usually present only minute holes that do not appear to reach in so far as the rhinal chamber. Viewed from above, we are to observe that the cranial and frontal

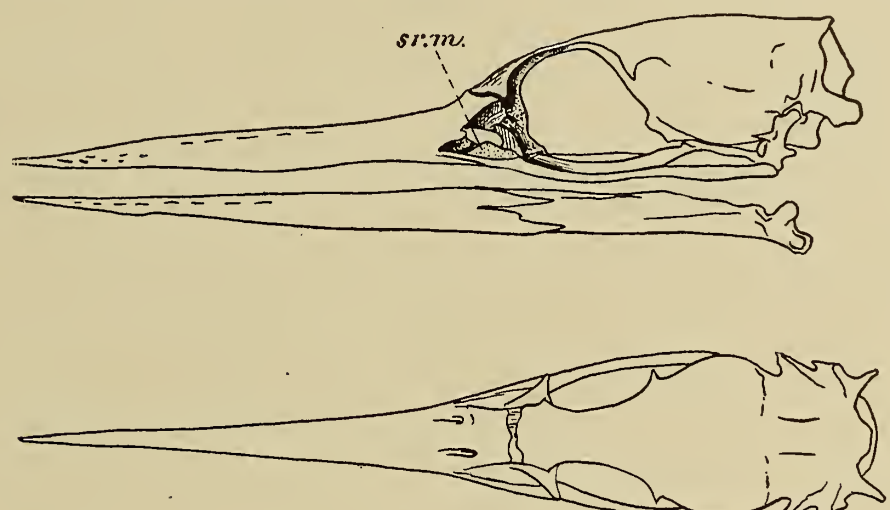


FIG. 3. Left lateral view of the skull, including mandible, of a specimen of *Anhinga anhinga*. Natural size, in outline, by the author from specimen 18259 of the Coll. U. S. Nat. Museum. *sr.m*, the supramaxillary bone.

FIG. 4. The same skull, seen from above. Mandible removed.

region are somewhat narrow and elongated; the former being smooth and moderately rounded, the latter flat and measuring about half a centimeter between the sharp edges of the superior peripheries of the orbits. For its hinder half, longitudinally, this part of the skull presents a low, median prominence, created by the approach upon either side, of the extensive, though shallow, crotaphyte fossa. We may also see, upon this aspect, the conspicuous *exoccipital processes.* They project almost directly backwards, and only slightly outwards. Posteriorly, the superior occipital area is seen to be bounded above by a sharp and raised line, much curved, which distinctly separates the occipital from the parietal region of the skull. The foramen magnum is very large, and subcircular in outline, its mid-vertical diameter being scarcely shorter than its transverse one. The unnotched condyle is of good size, hemispherical in form, and sessile.

Seen upon lateral aspect, we are struck with the open, shallow auditory fossa, which is overhung by a raised squamosal ridge, the squamosal process being small. Anterior to this region the lateral wall of the brain case is extensive, smooth and convex, otherwise presenting no special characters. The orbits are large, being continuously circular in front and above, the curve extending from the very short post-frontal process to the lower end of the lacrymal bone. No osseous septum divides these cavities, and a large, median, heart-shaped foramen occupies the central part of the anterior wall of the brain-cavity, from which, during life, the olfactory nerves pass out. Below this another median opening exists, of no inconsiderable size. It is the anterior common aperture of the optic nerves, and it is flanked upon either side by a vertical, scale-like flake of bone, extending forwards. The parial grooves for the first pair of nerves faintly mark the orbital roof above; each one leads to a corresponding foramen found over either *pars plana* in front. A pars plana or ethmoidal wing is oblong in form, and taken in connection with the lacrymal, makes a very complete osseous partition standing between the eye-socket and rhinal cavity. The mesethmoid is small, and is carried forward for a short distance as a thin median plate of bone, with a free anterior, thin edge. In the forepart of the nasal cavity there are two small foramina, in the otherwise solid wall, which lead forward into the cancellous tissue filling in the upper osseous beak. They are placed side by side. A *lacrymal* is a peculiarly twisted bone, articulating above with the frontal and nasal. It has an external transverse antero-posterior deep groove above, below which the bone becomes, as it were, twisted and expanded, into a broad quadrilateral plate. This stands transversely and forms, with the corresponding pars plana, the anterior orbital wall. The lacrymal reaches down to the zygoma and is a free bone. In front it has, articulating with its antero-lower angle, a scale-like piece, that stands vertically and rests for its entire length upon the upper surface of the maxillary. This is the *supra-maxillary.* (Fig. 3 *sr.m.*) Each zygoma is twisted and much flattened. Anteriorly, their broader surfaces lie in the horizontal plane, while the posterior moieties are in the vertical one. The peg-like, articulatory nibs at their hinder ends for the quadrates are very small. Looking at the skull from a direct inferior view, many of the points already described can be distinctly seen. This is due to the peculiar flattened conformation of the cranium. Indeed, the form of the brain-case indicates that *Anhinga* has an elongated, vertically compressed brain, but relatively not as much so as it is in a Cormorant, where it is also wider. The basi-temporal area is small and triangular, with moderately prominent paroccipital processes, each one descending from one of its postero-external angles. The anterior apex of the basitemporals is run out as a scale-like point, which underlaps the meeting of the thoroughly open *Eustachian grooves.* The usual foramina for the facial, glossopharyngeal, vagus and hypoglossal nerves, and the internal carotid arteries are plainly seen in this region. They are quite distinct from each other, and, as a rule, nearly circular in outline. The rostrum of the sphenoid is a very delicate, rod-like bone that is extended backwards in the median line under the cranium as far as the eustachian entrance, as a sharpened osseous ridge. In front it fuses with the mesethmoid. For their posterior moieties, the *palatines* are thoroughly coössified in the middle line, where they send down a faint crest from the sutural juncture. As thus constituted the common bone lies in the horizontal plane, with postero-external angles but faintly indicated, but with a short process extending directly backwards from either side of the united facets for the pterygoids. Anteriorly, the palatines are much narrower, where they are also in the horizontal plane, and mesially separated by an elongated opening that leads above into the rhinal chamber. Their distal ends run forward to fuse with the nasals, maxillaries, and premaxillaries.

The *maxillo-palatines* are very wide apart, and each one is simply a subvertical, thin, plate-like scale of bone for the most part free behind, but fusing with the usual bones in front. A shallow, medio-longitudinal groove marks the united palatines behind, and this is occupied by the slender, presphenoidal rod. A *quadrate* has a small, spine-like orbital process; a compressed mastoidal head of no great size, which is barely divided into two facets; a large, antero-posteriorly disposed facet for the mandible which is separated by a pronounced cleft from a much smaller one, the entire outer side of which is occupied by the pit for the end of the zygoma. The bone I believe to be pneumatic.

The *pterygoids* are flake-like, flattened bones with very sharp edges, and with very distinct ends bearing the articular facettes for the bones with which they articulate. Each pterygoid has a length of a little more than a centimeter. A circlet of small "sclerotal plates" are found in either eye, and the hyoidean apparatus is but feebly developed. I have not examined the ossicles of the ear. Conforming to the shape of the cranium and superior mandible, we find the lower jaw assumes the form of a long and narrow V. The ramal sides are not deep; there is no ramal vacuity; and the bone gradually tapers to a sharp point in front. From the nature of the splenio-dentary articulation—the thin bones being feebly wedged together there—the mandible is of a consequence very weak at that point. A considerable symphysis exists, with the barest rudiment of a median, inter-ramal spine present. For the most part, the upper and lower borders of the bone are rounded, though the supero-dentary edges, from sphenial articulation to apex are inclined to be cultrate. Either coronoid process is very much reduced, while between it and the articular cup for the quadrate, on the mesial aspect of the ramus, is a long foramen of an ellipsoidal outline, entering the inner structure of the jaw. Each hinder end of the mandible is, as usual, constructed to articulate with a corresponding quadrate. On the upper side of one there is a deep, rather narrow, obliquely-placed cup—its mesial end being the anterior one. This is for the *inner* articular facet of the foot of the quadrate. In front of this is a small, nearly flat, articular surface, and it is for the *outer* facet of the quadratal foot. Facing directly forward, and standing on the postero-internal edge of the cup is still another small facet, intended for a corresponding one on the same bone. These articular cups develop no inturned mesial processes, but the usual pneumatic foramen is present. The articular processes standing out behind, are of good size, of a quadrilateral form, and so twisted that the lateral surface in either case looks slightly upward and, to a much greater degree, outward.

Of the Axial Skeleton.—Endowed as it is with special points of interest, much has been written upon this part of the anatomy of *Anhinga*. It has been touched upon with greater or less elaboration by Brandt (Mem. de l'Acad. Imp. Sci. de St. Pétersbourg, tom. v., 6ime Série, Sect. de Sc. Nat., 1839), by Mivart, in his memoir in the T. Z. S., already cited, by Garrod (Coll. Sci. Mem., p. 334), by Donitz (Archiv für Anat. u. Phys., 1873, p. 357), and by Hunter (Essays and Obser., 1861, v. 11, p. 328), and by others. Most of these writers have been attracted by the peculiarities seen in the spinal column, which I will now proceed to examine.

In the *atlas* we find the articular cup of the condyle perforated near its upper border. Its neural arch is nearly as deep as it is wide, and from it projects behind, upon either side, a conspicuous little spine. The small hyapophysis of this vertebra also projects posteriorly beyond the centrum. From the *axis* to the seventh inclusive, the vertebræ are especially notable for being of no great caliber in point of size, and at the same time remarkably elongated. A low, sharp neural ridge and hyapophysial spine characterize the axis. Its postzygapophysial part is welded into a common plate of bone, with the articular facets upon its under side. Upon its ventro-posterior aspect an open channel is formed by a curling downwards of bone from the centrum upon either side. This traverses the entire length of the vertebral body in the third, fourth, fifth, sixth, and seventh vertebræ, but becomes less and less marked. On the eighth it is strong again, running between the enormously long parapophysial processes. In the ninth it is the subvertebral arterial channel, and is arched over with bone anteriorly. This remains to be the case to the thirteenth inclusive, while in the fourteenth the channel disappears behind, though the covered arterial passage still persists on the antero-ventral aspect, beneath the centrum. Both are absent in the fifteenth vertebra. Parial parapophysial spines first appear in the *axis*, where their distal apices fuse with the bone posteriorly. These spines, though present, are by no means a prominent character in the third to the seventh vertebra inclusive. Suddenly in the eighth they become remarkably developed, and are nearly as long as the bone itself. In the ninth they at once commence to shorten again, and this rapidly continues to be the case, until they, after somewhat changing their character, have entirely disappeared in the seventeenth vertebra. A most remarkable series of "lateral canals" exist in these vertebræ. I note them first in the axis, where they are of capillary dimensions and run nearly the entire length of that elongated bone. Anteriorly, either one opens at the base of the odontoid process, the posterior opening being on the side of the vertebra near the postzygapophysial base. In the *third vertebra* these canals are almost imperceptibly increased in caliber, and open upon either side, anteriorly, in a *slit* which is seen to exist between the prezygapophysial facet and the very much vertically compressed facet of the centrum. Behind, it opens a couple of millimeters in front of the articular surface of the centrum. But little change takes place in this particular in the fourth to the seventh vertebra inclusive, except that in the fifth, sixth and seventh a minute foraminal opening pierces the canal on either side about the middle of the bone on its ventral aspect. In the eighth vertebra the caliber of the lateral canals is about doubled and their posterior openings are moved far forwards so as to be found on the side of the vertebra, above the base of the enormously elongated parapophysial process; and between two fringe-like, long, ossified tendons that are attached to and especially characterize this bone of the vertebral chain. With their anterior openings remaining practically the same as described above, and the hinder ones just posterior to the parapophyses, no change is noted in the ninth except an increase in point of the size of the tube on either side. This increase goes on gradually to include the eighteenth vertebra, in which bone these lateral canals last appear. In the seventeenth they are very short, truly lateral, and somewhat compressed from above downwards; markedly most compressed in the eighteenth.

The *neural spine*, feebly developed in the third vertebra, becomes a prominent character of the fourth, where it occupies the posterior moiety of the bone, as a conspicuous blade-like crest, with rounded superior margin. In the fifth, sixth, and seventh this character disappears; in the eighth it is feebly present; in the ninth it is a roughened tubercle, entirely vanishing again in the tenth to the fifteenth inclusive. In the remainder of the series, back as far as the pelvis, it is large and of an oblong form, with thickened superior border. Throughout the dorsal vertebræ, ossified tendons of great length are coössified with this spine, projecting backward in the leading dorsals, and both backward and forward in the ultimate ones.

A low, sharp, hæmal spine occurs on the *ninth* vertebra; it being at the anterior part of the bone, on the parapophysial bridge that closes in the passage for the carotids. It is still better developed on the tenth; where sharp lateral ridges begin to show, one upon either side of it. All these processes are very pronounced in the thirteenth and fourteenth, while in the fifteenth their entire character is changed. In it the lateral ridges almost entirely disappear, and an enormous, quadrate hæmal spine is thrown down from nearly the entire length of the centrum. In the sixteenth it is not quite so large, and its hinder angle is produced backwards. A remarkable change is seen in the seventeenth vertebra, where the ventral aspect of the centrum is very much broadened, quite flat, and the little hook-like, laterally-compressed hæmal spine occupies a mid-position on the posterior border. In the eighteenth, ninteenth and twentieth the process is practically absent, and the great breadth of the centrum gradually narrows again, as its lateral margins are deflected. This form sees its extreme in the twenty-first vertebra, where the centrum is markedly compressed from side to side, and the aforesaid lateral margins are, ventrally, converted into a double hæmal spine.

In the twenty-second and twenty-third the spine is single, and the transverse compression of the centra is most apparent, being present in a marked degree.

Anapophysial ridges are more or less conspicuously developed in the ninth to the fourteenth vertebræ, inclusive, and in the dorsal series proper, are long and broad, and, as said above, are provided with fringe-like metapophyses frequently of considerable length.

In the first eight cervicals, the anterior articular facets are placed *laterally* upon either side of the neural canal, and their surfaces face forwards and towards the median plane. In the ninth vertebra these facets are, as it were, rotated backwards, so as to be *above* the neural canal, and face towards the median plane, and very slightly dorsad.

So in the articulation of the eighth vertebra with the ninth, a decided angle is made—nearly a right angle—with its salient point to the front. This also occurs between the ninth and the tenth and so on down the chain, becoming, however, less and less marked, disappearing entirely after the fifteenth, after which the vertebræ articulate in a straight line. The extremities of the long parapophysial processes of the eighth vertebræ articulate in the shallow grooves on the forepart of the ninth vertebra, on its ventral aspect.

Garrod has said that "Donitz figures a pair of accessory bony bridges on the dorsal surface of the vertebra following the most lengthy one, which must evidently, therefore, be the ninth. He, however, speaks of it as the eighth, which seems to me to be an error depending on the omission of the consideration of the atlas, because in *Plotus anhinga* (both from Brandt's figure and my specimens) it is most certainly the ninth, as it is in *Plotus novæ-hollandiæ*, *Phalacrocorax carbo*, and *P. lugubris*. I have, however, not seen *Plotus levaillantii*."

"Donitz attributed the peculiar kink of the neck of the Darters, which it is impossible to obliterate without lacerating the surrounding muscles, to the presence of the bony bridges he describes; in this, however, he is mistaken, it depending on the above-mentioned peculiarity in the eighth cervical vertebra, by which it is angularly articulated with the seventh and ninth vertebræ, the upper genu being posterior, and the lower anterior. In further verification of this, it may be stated that in *P. anhinga* the bony bridges do not exist, and yet the kinking is most strongly marked." (Coll. Scientif. Mem., pp. 336, 337.) The bridges here spoken of are also absent in my specimen of *A. anhinga*.

The neural tube is not very large in the first eight cervicals, where it has more or less a cylindrical form posteriorly, but becomes somewhat antero-posteriorly compressed as we gradually pass towards the fore end of the vertebra. Increasing again in size after the ninth, it seems to attain its greatest capacity in the sixteenth, seventeenth and eighteenth, to become small and cylindrical once more as it passes through the dorsal series. In the ninth and tenth vertebræ the anterior opening of the neural canal lies in a plane which is about perpendicular, in each case, to the plane in which the posterior opening is found. That is, upon direct dorsal view of either of these two vertebræ, the posterior opening of the neural canal is not in sight, while we look almost directly into the anterior opening.

On the sixteenth vertebra we find the first pair of cervical ribs; they are long and slender and without uniform processes. We find also a large pair of free ribs on the seventeenth cervical vertebra, which commonly have unciform appendages. These are anchylosed to the bone, and are large and broad. Next to these two pairs of cervical ribs, we meet with three pairs of true dorsal ones, they all having large costal processes, and all joining with the sternum by means of their hæmapophyses. There are two pairs of pelvic ribs, the first having stunted costal processes, though its hæmapophyses join with the sternum. In the last pair the unciform appendages are always entirely absent, and the costal ribs do not reach the sternum. Briefly then, there are *seven* pairs of ribs in this Darter, and this I believe to be generally the arrangement in all typical Cormorants.

Several of the authorities I have referred to above have both described and figured the *pelvis* of an *Anhinga*, and the bone possesses a number of interesting characters. *Fifteen* vertebræ of the spinal column fuse together to form its "sacrum." The leading *six* of these throw out their transverse processes to coössify with the ventral surfaces of the anterior portions of the ilia. The centra of the first *three* are markedly compressed transversely, the first one being very deep, the next less so, still less so the last. A large hæmal spine is also found on the first, which becomes rudimentary on the one behind, to be entirely absent in the one next in order. Two or three vertebræ throw out their processes to abut, upon either side, against the ilia at points just posterior to the cotyloid rings. Posterior to these, the outer extremities of the processes of the vertebræ completely fuse with the inner borders of the ilia; while on either side, from the acetabulæ all the way to the tail, occurs a row of interapophysial foramina, a feature so characteristic of the pelves of the Cormorants. The last vertebra, though not free, is to some extent individualized, and the extremities of its transverse processes may not so completely ossify with the ilium on either hand, which latter bones are here drawn out into peculiarly elongated posterior processes. Viewed upon its dorsal aspect we are to note that the anterior portions of the ilia are much horizontally expanded, while the narrowest part of the pelvis is just in front of the acetabulæ, where either iliac border shows a marked concavity. Thorough fusion of the internal iliac borders and the "sacral crista" takes place, and not even do the usual "neural canals" or "grooves" remain open posteriorly. This is well shown in *Plotus levaillanti* (Pl. XXI., Fig. 1). In front the iliac borders develop a raised emargination, and a strong brush of coössified tendons always project directly forward from the diapophyses and neural spine of the leading vertebra of the "sacrum." Passing to the post-acetabular portion we find that the pelvis is broader than it is in some of the Cormorants, and we are particularly struck with the prominent crests formed by the union of the internal iliac borders and the sacrum. The neural arch and the common neural spine of the latter is also conspicuously raised in this part of the pelvis. This begins moderately about opposite the cotyloid rings, and increases as we advance towards the tail.

This elevation of the center and margins causes the formation of longitudinal depressions between them, and down the center of either one of these we find the row of interapophysial foramina, to which reference has already been made above.

Some Cormorants seem to have a fairly well marked *propubic spine*, and there is an indication of the rudiment of such a process in the *Anhinga*. The internal circumference of either cotyloid ring is smaller than the external, and these cavities are brought up very close to the sacrum. Of enormous dimensions is the ischiadic foramen; it has the effect of absorbing nearly all the ilium above, and to some extent behind it; while below, it makes the neck of the ischium very narrow indeed. In form this large foramen is subelliptical. The "obturator foramen" opens into the obturator space, which latter is also extensive, and the pubic style which bounds it below as far as the point where it meets the ischium, is very slender and frail. Beyond this, the pubic bone is in close contact with the lower margin of the ischium, where it is very considerably stouter, as it also is after it becomes suddenly deflected behind after passing the extreme distal angle of the ischium — precisely as as it does in typical Cormorants.

A deep, triangular ilio-ischiadic notch, between the here very narrow ilium and the far broader ischium, indents the posterior pelvic border.

The antitrochanters are prominent, and the facet on either one of them looks forwards, downwards and slightly outwards.

Ventrally, the "pelvic basin" is seen to be fairly capacious; the "sacrum" is considerably enlarged opposite the acetabulæ and beyond; the exits for the nerves of the sacral plexus are double; finally, in front, we see the horizontally spreading ilia, with the compressed vertebræ, dipping down anteriorly so far ventrad.

There are *six* free caudal vertebræ in the skeleton of the tail of this Darter, plus a large pygostyle. This latter bone is drawn out supero-posteriorly, and the long superior edge is very sharp. Its antero-inferior angle is enlarged, with flattened surface below. Beyond this, the inferior border gradually contracts and becomes rounded. In front there is an extensive pit for articulation with the last caudal vertebra, and above this there is a small opening where the spinal cord enters this bone.

The centra and their articulatory facets are large in these vertebræ, but the spinal canal is of no great caliber. In mid-series the neural arch and spine, and the forward-projecting prezygapophyses are conspicuous. A good-sized hæmal spine also characterizes the last four vertebræ, and in each case it extends forwards to underlap the bone next in advance. As a rule the transverse processes are rather short and stumpy, being entirely rudimentary in the sixth caudal.

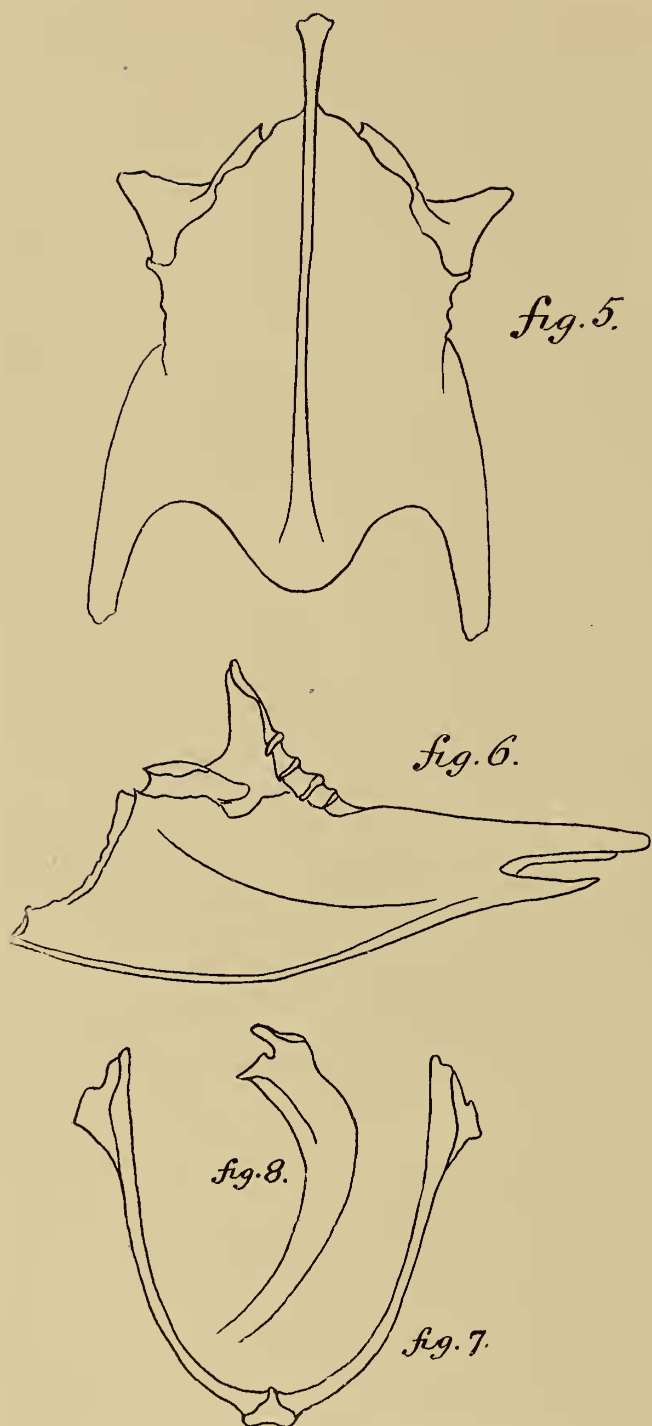


Fig. 5. Ventral aspect of the sternum of *Anhinga anhinga*.
Fig. 6. Left lateral view of the same bone shown in Fig. 5.
Fig. 7. Anterior aspect of the *os furcula* of *Anhinga anhinga*.
Fig. 8. Mesial side of the scapular end of the same bone shown in Fig. 7. All the cuts are natural size from the specimen (No. 18259, Colls. U. S. Nat. Mus.). Outline drawings by the author.

The Sternum and Shoulder Girdle.—Many of the characters of the sternum of a Darter essentially agree with the corresponding ones as they occur in the sternum of such Cormorants as represent the genus *Phalacrocorax*. Its carina dies out on the under surface of the body before arriving at the mid-xiphoidal process behind; and is deep only in front, where it protrudes forwards, with a sharp anterior border, and bears a large facet, occupying the carinal angle, for articulation with the os furcula. Only the merest rudiment of a manubrium is to be seen at the usual site; possibly the process is entirely absent in some specimens. A wide concave notch separates the coracoidal grooves mesiad, and the large, elongated coracoidal facets above them. Large, acutely triangular costal processes are developed, each one projecting outwards at an angle of about 45°, and very slight forwards. The costal borders are short and much contracted; either one supports four transverse hæmapophysial facets. Posterior to the costal borders the sternum widens, and its lateral margins are sharp. Its hinder border is also sharp. Two large, broadly concave notches exist here. They give rise to long, lateral xiphoidal processes, and a shorter mid-xiphoidal process. On its thoracic aspect the sternal body as a whole is well concaved — uniformly so, as the position of the heel beneath is but barely indicated down the median line. The form and proportions of the sternum in *Anhinga* are well shown in my figures 5 and 6.

The *os furcula* is of the typical U-shaped pattern, with large, expanded clavicular heads. There is but the barest rudiment of a hypocleidium below, while a facet is present on the nether side of it, for articulation with the carinal angle of the keel of the sternum. Either broad, laterally-compressed clavicular head, is bent rather abruptly downwards; a projecting, facet-bearing shoulder is developed for the coracoidal articulation. Above either of these facets we note a strong process pointing backwards, which, when the os furcula is articulated *in situ*, rests upon the summit of the corresponding coracoid. (See Figs. 7 and 8.)

Both Darters and Cormorants have unusually long *coracoids*. In *Anhinga* the coracoid is longer than the femur. Its sternal end is considerably expanded, and shows a wide and rather deep excavation on its posterior aspect for the coracoidal groove and facet upon the sternum, while anteriorly the corresponding surface is narrow and shallow. A costal process is not developed, but that border is convexly rounded and sharp. The shaft of this bone is antero-posteriorly much compressed, and in front a strong, muscular line marks it longitudinally, especially near the sternal end. The scapular process is much aborted, but the head is quite massive and tuberous. Its entire antero-mesial aspect is occupied by an oval facet for articulation with the clavicular head of the furcula. The scapular facet is small, but the glenoid surface is of fair size.

Quite uniform in width and moderately pointed distally, the thickish blade of a *scapula* has its posterior extremity but very slightly bent outwards. The anterior end of this bone is wide transversely, and the long acromial process decidedly tilted up. The glenoidal process also stands out rather prominently, while the articular facet for the coracoid is comparatively small. Just posterior and beyond the glenoidal facet, the border of the scapula is broadly rounded, but is sharp all along its mesial edge, clear to the tip of the acromial process. It is only the distal third of the bone that is vertically compressed and at all blade-like.

On the Appendicular Skeleton.

Being thoroughly non-pneumatic, the long bones of the limbs in *Anhinga* are solid and heavy. Although not so very far from being double the size, the humerus of *Fregata* weighs about the same as the humerus of the species of Darter we are now describing. In *Phalacrocorax urile* the ulna is somewhat longer than the humerus, while in this Darter the humerus is considerably longer than the ulna. These are interesting facts.

In *Anhinga anhinga* the *humerus* has a length of about 13 centimeters, and it presents the usual double sigmoid curve. This latter, however, is far better seen upon a superior view of the bone, rather than upon its anconal aspect. (See Fig. 9.)

fig. 9.

fig. 10.

fig. 11.

Fig. 9. Anconal aspect of right humerus of *Anhinga anhinga*. Fig. 10. Anterior view of right femur of *A. anhinga*. Fig. 11. Right coracoid of *A. anhinga*. Seen from in front. All drawn in outline, natural size, by the author, from Spec. No. 18259, Coll. of U. S. Nat. Museum.

The proximal end of the bone is narrow and elongated, merging with the shaft very gradually. The radial crest is a low, long ridge of uniform height; while the ulnar crest and tuberosity are prominent and are bent anconad. This creates a deep valley between the true articular humeral head and the ulnar protuberance. The excavation over which the latter arches, and where the pneumatic openings usually occur in other birds, is very shallow, and indeed so very much so that really no fossa may be said to exist there at all. A marked diffuse excavation exists upon the palmar aspect of this part of the humerus; this is spread out over a regular area just within the distal half of the radial crest, but joins with a far narrower and somewhat deeper strip that bounds the humeral head distad, and lies on the opposite side of the bone to the ulnar crest. All this excavation is powerfully marked in *Phalacrocorax*.

The humeral shaft proper is subcylindrical in form, being of nearly uniform caliber for the middle third of the bone. At the distal extremity all the most usual ornithic characters are prominent and pronounced. The olecranon fossa is shallow, but the ulnar and radial tubercles jut out very conspicuously, though not as markedly so in proportion as in the Cormorants.

The *ulna* has a length of about 11.5 cm. and is moderately bowed from one end to the other. The points of attachments for the quill-butts of the secondary feathers present quite a striking feature, and each seems to consist in a small pitlet, with its upper and lower edges very slightly raised, but in a manner hardly to suggest the idea of a "papilla" or "tubercle" as I have so frequently described them for many other kinds of birds.

The ulna develops a distinct lip of bone, that curves partly round the head of the *radius* when they are articulated *in situ*. This latter bone, hardly half the caliber of the ulna, shows barely any bowing or curving at all throughout its continuity. Distally it is deeply grooved on top for the passage of tendons, while a deep circular cup for articulation with the radial tubercle on the humerus surmounts its head or proximal extremity.

The two usual ossicles, *radiale* and *ulnare*, compose the skeleton of the wrist in the adult.

The *carpo-metacarpus* has a total length of 6.5 cm. and is characterized principally by a deep pit on the palmar size of the head, between the pollex metacarpal and the process for muscular attachment. This is also a very general phalacrocoracine character. The shafts of index and medius metacarpals are very straight, and the latter about as long as the former, has not more than about one fourth its bulk, and is compressed throughout, the flat surface of the opposed side being presented to the shaft of the former. The pollex metacarpal is short, and, on the whole the bone is not very unlike what we find it to be in the Cormorants.

No perforation exists in the dorsal expansion of the proximal phalanx of the index digit, and none of the terminal joints of either the thumb or the other two fingers have claws at their extremities. The one belonging to the medius is comparatively long, and very sharply pointed.

I am not familiar with the existence of any special sesamoids about the articulations in the skeleton of the anterior extremity, at places where they exist in some Auks and other water birds.

Passing to the PELVIC LIMB we find a *femur* with a length of 5.5 cm.; a tibiotarsus with a length of 9 cm.; a tarso-metatarsus of 4 cm.; an accessory metatarsus of 1.4 cm., which is nearly equalled by the patella — it having a length of 1.2 cm. In the foot, the skeleton of hallux measures 3.1 cm., the inside toe 4.7 cm., middle toe 7.5 cm., and outside toe 8 cm.— the ungual joints being included in each case.

Proportionately the femur is longer in *Anhinga* than it is in *P. urile*, and is not bowed so much in the antero-posterior direction. The summit of the bone is capped off with the articular surface, above which neither the caput femoris nor the trochanterian crest, rises. The external condyle is more prominent and lower on the bone than the internal one, and is deeply cleft for articulation with the head of the fibula.

Neither the "rotular channel," nor the popliteal fossa are very deeply excavated; and on the head of the bone the pitlet for the ligamentum teres is also quite shallow. The muscular lines of the shaft are distinctly defined both in front and behind.

With its shaft somewhat antero-posteriorly compressed, and very slightly bowed to the front, the *tibio-tarsus* presents us with pro- and ectocnemial processes well developed, and a cnemial crest that rises above the summit of the bone. Of considerable length is the conspicuous ridge for articulation with the fibula, and at the antero-distal extremity of the shaft we observe the presence of the osseous bridge under which the tendons pass in life. This end of the bone inclines as it were to the inner side, so that if the mid-vertical axis of the large internal condyle were extended it would be removed from and parallel to, the longitudinal axis of the shaft, rather than being in the same line with it.

Both extremities of this bone, as is the case with the extremities of the tarso-metatarsus, are more or less massive and enlarged as compared with the shafts of the same. Coming to the *fibula*, it is very interesting from the fact that it is *complete,* rather more so if anything than we find it to be in either *Pandion* or *Urinator*, and is only anchylosed to the tibio-tarsus by means of its enlarged and extreme distal end. This limited fusion of the two bones takes place at a point just above the external condyle.

Anhinga has a large *patella*, but proportionately not as large as we find it in the Cormorants. It is an oblong sesamoid, nearly equilateral, concave behind and convex anteriorly, where it is transversely perforated by a minute foramen for the passage of the *ambiens muscle.*

As will be seen from measurements above, the *tarso-metatarsus* is relatively a short bone of the leg; it is further characterized by having its somewhat broad shaft compressed in the antero-posterior direction and marked longitudinally upon both aspects by strong muscular and tendinal lines and grooves. The hypotarsus is strongly developed, especially the interno-lateral part of it, which, by a plate-like extension, has a firm attachment to the upper third of the shaft. Its posterior angle above is always thickened and doubly pierced for tendons. The externo-lateral part of the hypotarsus is small and it also creates by its form a groove and a foramen for certain tendons that pass through or over them during the life of the individual.

One or two small foramina pierce the upper part of the shaft in an antero-posterior direction, the most constant one making its exit behind to the inner side of and at the base of the hypotarsus. At the distal end the trochleæ for the toes stand well apart. The inner one of the three is the lowest, and juts out in a prominent way from the bone, and has a tubercle projecting from its lateral aspect.

The mid-trochlea is massive, not quite centrally located on the end of the shaft, and is the next lowest in point of position. The highest of all is the external one, and its outer part is produced the farther behind.

On the anterior part of the shaft in front, in the groove extending up from between the mid- and external trochleæ, occur *two* perforating foramina. The lower one makes its exit in the intertrochlear notch; the other on the shaft above it. Nearly all existing birds have only a *single* foramen at this point. It is even single in *Phalacrocorax.*

The free first metatarsal is large and strong, twisted upon itself, and with an elongated transverse facet for articulation with the hallux. The skeleton of the *pes* is remarkably well developed. The phalangeal joints, arranged upon the plan of 2, 3, 4, 5 for hallux to outer toe inclusive, are stout and strong, and the terminal ungual joints are, one and all, handsomely curved and sharply pointed at their extremities.

We now pass to the consideration of the osteology of the Cormorants, which it will be found agrees in many particulars with the species of Darter we have just been describing.

Observations on tha Skeletology of the Phalacrocoracidæ.[10]

A great many Cormorants of the world's avifauna, as I have before stated, belong in this family, and as far as at present known it is the only one represented in the United States, where, as heretofore noted, the nearly a dozen species and subspecies it contains have all been restricted to the single genus *Phalacrocorax.* Cormorants are a good deal alike in their osteology, and in this part of their anatomy, too, they have a good deal in common with the Darters. To give the salient features of the skeleton in this group I will draw upon the skeleton of *P. urile* in particular, as well as in general those of the collections of the U. S. National Museum, and also republish a short description, together with the figures illustrating it, of *P. per-*

[10] In his recent (1899) *Hand-List of Birds*, Dr. R. Bowdler Sharpe presents also a classification of the Cormorants (pp. 232–235). They constitute the first group of his Order (XXIII.) Pelecaniformes, and all are relegated to the family *Phalacrocoracidæ*, and this latter is divided into four (4) genera, viz: (1) *Phalacrocorax*; (2) *Pallasicarbo*; (3) *Nannopterum*, and (4) *Actiornis*. The first of these contains forty-two (42) species of existing cormorants, and ten (10) extinct forms; the second is represented by a single extinct type, the *P. perspicillatus*; the third contains only the singular cormorant of Narborough and the Galapagos Islands; while finally, the fourth genus is also represented by a single extinct form, the *A. anglicus* of Lydekker. In the United States we have some six (6) species and five subspecies of Cormorants, all of the family *Phalacrocoracidæ*. Through the constant energy and perseverance of Mr. Lucas, a large proportion of these Cormorants are represented in the collections of the U. S. National Museum by their skeletons, and through his kindness I have been enabled to study and compare all this material in the revision of the present memoir. The collection in question is now doubtless the finest of the kind in the world, and has in it the skeletons of more steganopodous birds than that of any other in existence.

spicillatus, Pallas's Cormorant, given by Mr. F. A. Lucas in the Proceedings of that institution for 1889 (pp. 88–94), also other material and figures by the same author.

When we regard the skull of *P. urile* from above, we observe that the cranium is very flat, and, across the parietal region, broad. Indeed, though large, the brain-

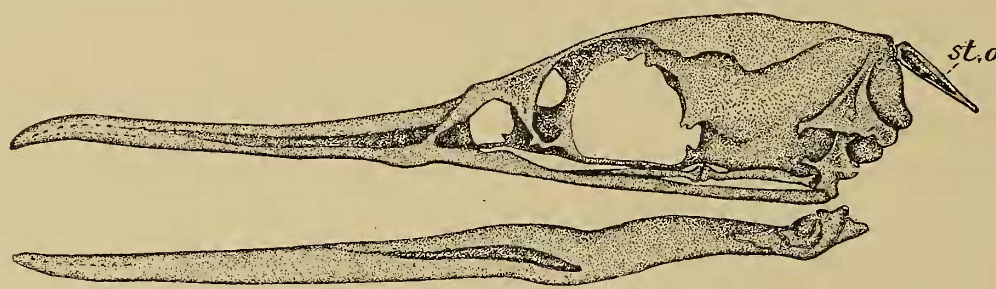


Fig. 12. Left lateral view of the skull of *Phalacrocorax urile*; nat. size. By the author, from a specimen in the Smithsonian Institution. *st.o.*, the occipital style. (See also Plate XXIV., Fig. 15.)

cavity is vertically compressed, and this is one of the first things to attract our attention as we examine the skull of this Cormorant. Between the sharp superior edges of the orbits the frontal region measures transversely about a centimeter, and this too is the average width of the not very mobile cranio-facial hinge. A broadish, shallow, longitudinal groove traverses the fronto-parietal region, and the well-marked crotaphyte fossæ fail quite to meet on top of the prominent, convex occipital elevation. The occipital line and crest are very sharp and ridge-like, and a free, *osseous, occipital style*, over a centimeter and a half long, articulates at a median point a short distance above the large foramen magnum, where these lines and crests meet. This style is distally pointed, has sharp supero-median and lateral borders, which give rise to supero-lateral surfaces intended for the attachment, on either side, of the posterior part of the temporal muscle. (See Fig. 12.)

The upper bony beak is somewhat broad at its base; is slightly longer than the cranium; narrow for its anterior half; edges semi-cultrate; very moderately decurved at the end; culmen broadly convex from side to side; flat beneath; external narial apertures absent. A groove passes down upon either side, which is deepest at those sites where nostrils occur in most birds that have them. There is a minute foramen on either side, communicating with the rhinal chamber. The lateral processes of the cranium are almost entirely aborted, and the orbital cavity behind freely opens into the cranio-zygomatic space, and the cranial wall here is bulging, smooth, and convex. At the occiput the usual processes are fairly well developed, and the quadrato-mandibular articulation, on either side, is located far posteriorly as in an alligator.

In their essential characters, the quadrates, the pterygoids, the palatines, and the maxillo-palatines agree with what we found above in *Anhinga*. *Phalacrocorax* also has a small *supramaxillary*, or as Parker called it, a "post-maxillary," and according to him it is large in *P. carbo*, and small in *P. graculus*.

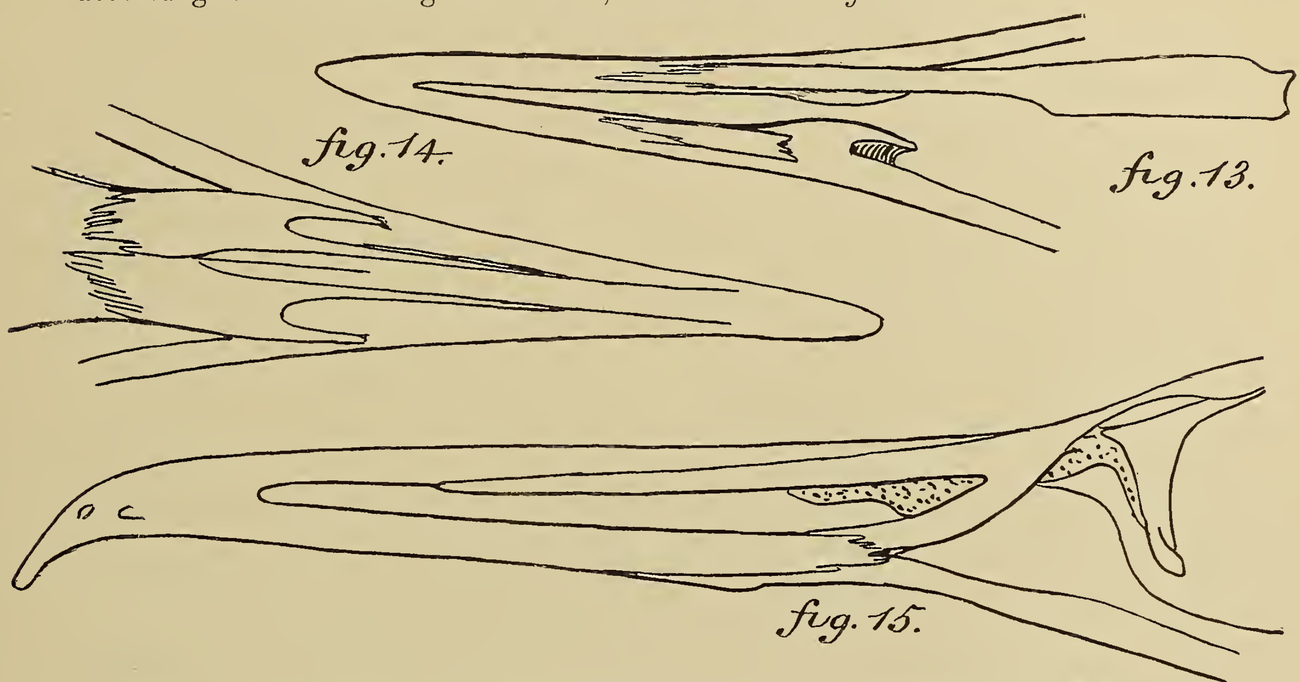


FIG. 13. Palatal region of a young *Phalacrocorax urile*, showing the maxillo-palatine of the right side.

FIG. 14. Dorsal aspect of anterior part of the cranium of a young *Phalacrocorax urile*, showing the absence of a fronto-nasal hinge.

FIG. 15. Lateral aspect of beak of a young *Phalacrocorax urile*, showing the open condition of the nostril. All three figures drawn by Mr. F. A. Lucas from specimen No. 12732 of the collections of the U. S. Nat. Museum, and enlarged by means of the camera lucida.

Regarding the *maxillo-palatines* and related bones in the skull of a Cormorant, it seems that ornithotomists do not quite agree as to the exact sutural boundaries, and it seems that Mr. W. P. Pycraft, of the British Museum, some time ago printed an article on the osteology of certain steganopodes, in which he was at variance with anatomists upon this point. Desiring the opinion of Mr. Lucas upon this point, he has kindly furnished me with the following remarks, and illustrated them with some drawings, which latter are here reproduced as Figs. 13, 14 and 15. In his communication he says: "Some difference of opinion exists as to just what portions of the maxillaries represent the maxillo-palatines, and while I do not like to differ with my friend Mr. Pycraft for fear I be on the wrong side, yet, after carefully considering the subject, the conclusion is forced upon one that the posterior extensions of the maxillaries are the maxillo-palatines."

"By the kindness of Mr. R. C. McGregor and Mr. Curtis Clay Young the Museum some time ago came into the possession of an extremely good series of Cormorant skulls of all ages, and by means of these it is possible to trace the process of ossification very well. These seem to show that the desmognathism of the Cormorant's skull is caused by the growth of bone between the maxillaries, and is not due to any outgrowth of those bones themselves."

"This ossification commences between the backward processes here considered as the maxillo-palatines and progresses until they are firmly united. The union of the anterior portion of the maxillaries occurs later and is due to the extension of ossification into the tough lining of the roof of the mouth, and there is frequently a small space between the maxillaries which remains open for a long time if not permanently" (Fig. 13).

"The formation of the fronto-nasal hinge (Fig. 14) is a secondary character, the bones so overlapping in young birds that there is no freedom of movement in this region."

"The absence of external narial openings is also a secondary character, for the young Cormorant possesses perfectly open nostrils while the cranium is almost as schizo-rhinal as that of a gull (Fig. 15). As growth proceeds the narial openings become more and more restricted, until about the time (the exact time is uncertain) that the young birds take to the water, not only the external openings, but those of the cranium have become completely filled."

Passing once more to the skull in the adult we find the interorbital septum is unossified, as is the greater part of the anterior wall of the brain cavity. However, we here find the "foramen rotundum" separated from the far larger vacuity above, by a transverse bony bar. A subcircular vacuity also occurs in the mesethmoidal plate; and the sphenoidal rostrum is not as large as the zygoma.

Phalacrocorax urile differs from the *Anhinga* inasmuch as in it the *pars plana* does not ossify; and in the form of its lacrymal bone. One of these in this Cormorant is seen to be fused with the frontal bone and nasal above; is *laterally* composed; *not* in contact with the maxillary below, where it sends outwards a short process, and inwards a longer and slenderer one, the mesial end of which fuses with the mesethmoid (see Fig. 12).

This specimen (No. 18982, Coll. U. S. Nat. Mus.) lacks a *vomer*, and it was not to be found in my skeleton of *Anhinga;* in the latter, if it ever existed, it may have been lost—but I see in another place, where remarking upon the osteology of *P. bicristatus* (now *urile*) (*Science,* N. Y., v. 11, No. 41, Nov. 16, 1883, p. 640), I have said that in it "we observe a long attenuated vomer, terminating anteriorly in a free pointed extremity." But I am inclined to think that the vomerine ossification is not always a constant character in these birds. Ossifications of the eyes, ears and tongue agree in the main with the corresponding parts in the *Anhingidæ*, and have been more or less fully described above.

V-shaped in pattern, the *mandible* is a strong bone in birds of this family. This is due to the thickness of the rami, and not to their height, for they are rather low than otherwise; also to the unusual firmness of the dentary ossification with the other bones posterior to it, and finally to the total absence of a ramal vacuity—the mandible not being weakened at those points (see Plate XXIV., Fig. 17). Each dentary upon its mesial aspect shows a deep longitudinal groove. The articular ends are truncated posteriorly, though the postero-mesial angles are somewhat produced. Each of these articular cups appears to be connected with its respective ramus by a kind of neck, which is directed backwards and towards the median line. When seen from above, and the jaw is articulated *in situ*, this gives rise to rather an odd-appearing articulation. Either quadrate is thus entirely shut out of sight, with the exception of its externo-lateral process, the base of which does not come in contact with the mandible at all. The sides of the rami are *within* the quadrato-jugal bars, and rise somewhat above them. The pterygoids, owing to a special notch in each articular cup, are thoroughly exposed, but no more.

Of the Remainder of the Axial Skeleton.—Seventeen vertebræ are found in the cervical region of *P. urile*, before we arrive at one that bears a free pair of ribs. A small pair of rudimentary ones in this species are to be observed in the eighteenth vertebra. Now in *P. urile* these last are not liberated, while in the nineteenth and twentieth vertebræ the free ribs are long, well developed, and have anchylosed upon them large unciform processes. In the leading pair, however, either upon one side or the other, this last character may be absent. Such is the case on the left side of the specimen at my hand.

P. urile has its entire vertebral chain in many respects quite different from anything we described for *Anhinga*. We do not meet with the greatly elongated eight leading cervicals, and the abrupt change in character as we pass to the ninth one. Nothing of the kind occurs in the Cormorant, for in it the eight leading cervicals are quite in harmonic proportions in all respects with those that follow them. We nevertheless find in this Cormorant the same modifications, only in a far less marked degree, in the eighth, ninth and tenth vertebræ, which give this bird the power to draw back its head and with great rapidity to thrust it forward again, the point of flexure being between the vertebræ just mentioned. Anhingas catch all the fish they eat by spearing them with their sharp beaks while in active pursuit *under* water. The head is drawn back and then thrust forward like a spear, with wonderful rapidity and precision—the prey being transfixed on the closed, lance-like mandibles. When prepared to deliver the blow, the angle formed by the seventh and vertebræ points backwards, and the one between the eighth and ninth forwards, the eighth vertebra itself standing subvertically between them. Gannets and Herons have the same arrangement of these cervical vertebræ, but nothing like as well developed as we find it in the Darters. Bitterns show it well,[11] as do all our American Herons, and they *transfix* their prey, although they do not pursue it under water as the Darters habitually do.

P. urile has handsomely developed parapophysial spines on its cervical vertebræ. They are rudimentary on the atlas and axis, coming to be of good size on the third vertebra. From it on they gradually increase in length, but diminish in caliber, until we come to the tenth cervical. In it they are as straight as sewing needles, and as long as the centrum of the vertebra. They die out on the fifteenth cervical. The lateral canals are normally developed and of good size in the third vertebra at its anterior part. They very gradually increase in size down the series, until we arrive at the first vertebra bearing free ribs. On the other hand the hypapophysial carotid canal begins in the fourteenth vertebra, and terminates in the seventh; it never quite closes in so as to form a perfect tube, but comes very near it in the thirteenth vertebra. A large hæmal spine suddenly appears on the fifteenth cervical, and the character persists down the series, to include the leading two or three vertebræ of the pelvic sacrum. Hæmal spines are also found on the atlas and axis; and a strong neural spine first appears on the sixteenth vertebra, while on the eighteenth to the twenty-third inclusive they are very large, strong, oblong in form, and much in contact with each other in the dorsal region of the spine; the various articulations among the vertebræ are very close indeed. Here the centra are much compressed from side to side; the transverse processes narrow and spreading, and these latter have strong metapophysial spines interlocking at their extremities. But there is none of that luxuriant interlacing of ossified tendons that we see there, and on the neural spines and anterior iliac margins, as in *Anhinga*. *Phalacrocorax* is more or less free from that.

There are *three* pairs of large, strong dorsal *ribs*, bearing great, flat, anchylosed unciform appendages. By a graduated series of costal ribs, these vertebral ribs join with the sternum. The first pair of pelvic ribs likewise, by a very long pair of hæmapophyses, connect with the sternum. Small unciform processes also appear upon them, but not on the last pair of pelvic ribs that follow these. Nor do the

[11] See the author's reference to this in the American Bittern in *The Auk*, Vol. X., No. 1, January, 1893, pp. 77–78.

costal ribs of this pair quite reach the sternum. On the left side in the specimen before me there is also a "floating costal rib," with a length of nearly 3 centimeters. It lies close along the posterior border of the distal moiety of the ultimate hæmapophysis.

This last-mentioned bone in a specimen of *P. urile* articulates with the sternum on the left side, and no doubt from time to time such will be found to be the case in other species of *Phalacrocorax, i. e.*—the ultimate pair of costal ribs or hæmapophyses, upon one side or the other, or for the matter of that, upon both sides, may join with the sternum the pelvic ribs to which they belong.

In *Phalacrocorax* we find a *pelvis* very much like the one we described for *Anhinga*. The ilia are horizontally spread out in front, where they may be so thin as to present a number of perforating foramina. In the postacetabular region these bones come much closer together, both actually and relatively, than they do in the Darters. The interdiapophysial foramina also are present, a row upon either side of the *posterior sacral crista,* and they are very large just before we arrive at the first caudal vertebra. The internal iliac borders are not elevated here as they are in *Anhinga*. Cormorants of this genus also have the large obturator space; the enormous ischiadic foramen; the rudimentary propubis; and the same peculiarities of the postpubis.

Posteriorly, either ilium sends back a conspicuous process, and the two hold firmly between them the first free caudal vertebra. In some species, as *P. urile,* they may grasp two instead of one. An ilio-ischiadic *notch* is also present upon either side of the pelvis.

There seem to be *seventeen* vertebræ included in the pelvic sacrum to the *fifteen* we found in *Anhinga*. Six of these are beneath the fore part of the ilia; two more with aborted processes lie immediately between the large acetabulæ; two true dorsal ones follow these, and they have their lateral processes thrown out as abutments to the walls of the pelvis; finally seven more so-called uro-sacrals are to be counted between these and the first caudal.

Viewed ventralwise, the pelvic basin is seen to be deep and capacious. Another marked character on this aspect is the strong ridge or crest of bone on either side, which extends longitudinally backwards from a point below the cotyloid ring to the hindermost angle of the ischium. It is strongest directly below the great ischiadic foramen. This character is but feebly marked in the pelves of the Darters.

There are six caudal vertebræ and a *pygostyle*. The latter is large; pointed posteriorly, triangular in form, broad and flattened at its lower part behind, in front of which there is a hæmal spine. Hæmal spines are also found upon the last three caudals, and neural ones on them all. These tail vertebræ are large and strong, and the transverse processes on the fourth and fifth extend out considerably beyond the others of the series.

Sternum and Shoulder Girdle.—In the article in *Science* cited above it was said of the sternum of *P. urile* that it had "two shallow excavations on either side of the median line, occupying the entire xiphoidal margin or border" (p. 641). This no doubt was a *lapsus calami,* as no true Cormorant has more than one such excavation upon either side of the sternal keel. Apart from its greater size, the sternum in *P. urile* agrees in almost every particular with that bone as we described it for *A. anhinga.* The lateral xiphoidal processes, however, are comparatively not as long nor as narrow; nor are the costal processes of the sternum of the Cormorant relatively as lofty or as slender as they are in the Darter. Otherwise the two bones essentially

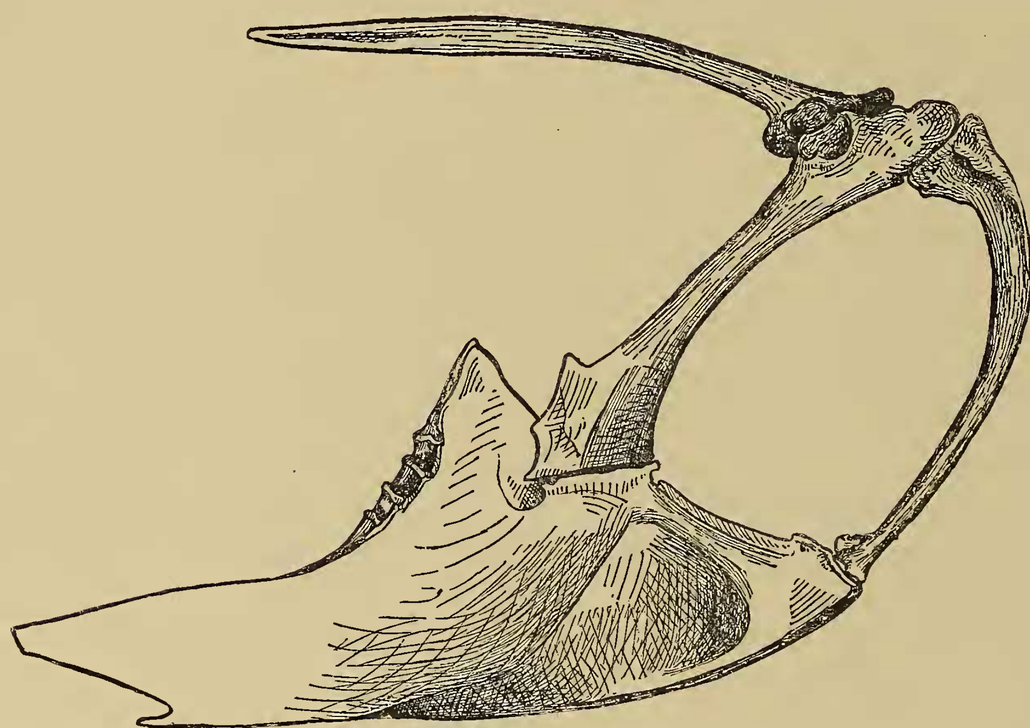


FIG. 16. Right lateral view of sternum and bones of the shoulder-girdle of a Cormorant (*Phalacrocorax urile*), nat. size, by the author, from a specimen in the collection of the U. S. Nat. Museum. (Compare this figure with Fig. 30 of Plate XXVI.)

agree. (Compare also the sternum of *Phalacrocorax albiventris,* Pl. XXVI., Fig. 30.) Again upon comparing the several bones of the *pectoral arch* in these two forms, we are once more at a loss to find any noteworthy differential characters. The *os furcula* in each are upon identically the same pattern; the *coracoids* are alike with the exceptions that in the Cormorant the bone is proportionately not as long; its sternal end is more expanded, and it has a broadly developed "costal process." In the case with the *scapula*, we find that the blade of it in the Cormorant is not as much curved, nor is the distal end of the bone at all bent outwards. (See Fig. 16.)

On the Appendicular Skeleton of P. urile.

Very little of the skeleton of this Cormorant is pneumatic. For the most part the bones are solid and heavy. Apparently air gains access only to certain parts of the cranium and lower jaw, other bones of the osseous system being completely non-pneumatic. This is especially true of the skeleton of the limbs, where all the bones typify in the highest degree the unaërated variety.

In a number of respects the bones of the *pectoral limb* of *P. urile* present characters which essentially agree with those upon the corresponding bones as found in the arm of an *Anhinga*, which characters have already been described above. In the *humerus* of *Phalacrocorax*, however, which is shorter than the ulna, the "pneumatic fossa" is profoundly concave, quite as much so as in those large species of birds in which the bone is pneumatic, or even more so than in some which show that condition. At its distal end the articular protuberance for the radius has an elongation at its proximal extremity which is bent over towards the mid-longitudinal axis of the shaft of the bone. The "oblique tubercle" for the ulna is more hemispherical than we usually find it in birds. At the proximal end of the *ulna* we observe a conspicuous projecting lip of bone, which contributes an additional surface for the radial articulation. Papillæ down the shaft of this bone for the quill-butts of the secondary feathers are in a single row and rather feebly developed. Both *radius* and ulna are somewhat bowed, and when articulated *in situ* they are in contact for their distal moieties while proximally a good-sized spindle-shaped interosseous space occurs between them.

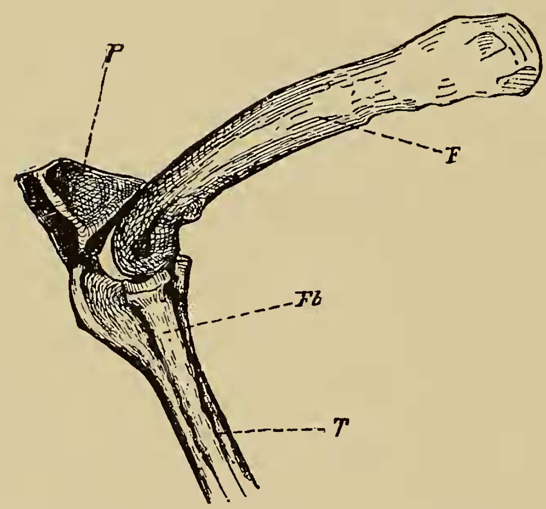
The characters of the skeleton of the hand are practically the same as we found them to exist in the manus of *Anhinga*. There are no distinguishing characters of any importance.

Gannets have the skeleton of their pectoral limbs in many respects like the Cormorants and Darters, but in them all the bones are completely pneumatic. When we come to consider the difference in the habits of the representatives of the three families, this is not so much to be wondered at.

Cormorants are more or less like the Darters too, in the osteology of their *pelvic limb*. There are more differences, however, to be found here than we discovered upon comparison of the pectoral extremities. *Phalacrocorax* has the *femur* proportionately stouter, shorter, and more bowed in the antero-posterior direction than it is in *Anhinga*.

We also note that the pit for the insertion of the *ligamentum teres* is more elaborately scooped out, and the trochanterian protuberance is produced far more to the front in the Cormorant, such hardly being the case at all in the Darter. The fibular and intercondyloid notches are very deeply sculpt, though anteriorly the rotular channel is unusually shallow.

The large trihedral *patella*, with its broad, flattish base is, as Garrod remarks, often laterally pierced for the passage of the tendons of the ambiens muscle.[12] The



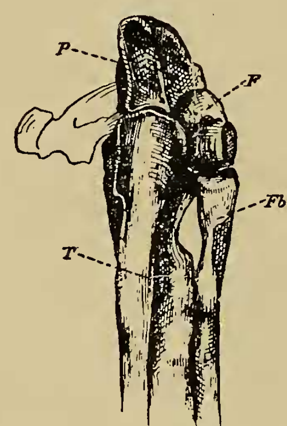


FIG. 17. Knee-joint of a Cormorant (*Phalacrocorax urile*); natural size. *F*, femur; *P*, patella (originally described by the author in *Science*); *Fb*, fibula; *T*, tibio-tarsus. Drawn by the author from a specimen in the Smithsonian Institution.

FIG. 18. Knee-joint of *Phalacrocorax urile*, seen from in front. Natural size. Letters signify the same as in other illustrations.

cnemial processes of the tibio-tarsus are fairly well developed and are confined to the anterior aspect of the head of the bone, where we also see a strong cnemial crest rising above its summit. For its entire length, the shaft is compressed in the antero-posterior direction, and the fibular ridge is long—standing well away from the side of the shaft. *Phalacrocorax* has the *fibula* about as well developed as we found it in *Anhinga*, it being *complete* and fused with the tibio-tarsus only at its distal end. When the bone is held vertically the internal tibio-tarsal condyle is the lower of the two on the extremity of the shaft.

Cormorants have a *tarso-metatarsus* differing in some marked particulars from that borne in the Darters. In the first place it is pierced by but one arterial foramen at its trochlear end, and its mid-trochlear process is the lowest on the shaft, rather than the inner one as in the Anhingas. Tendinal grooves, and their dividing lines up

[12] Garrod, A. H. Coll. Scientif. Mem., p. 198.

and down the shaft, back and front, also slightly differ, as does the form of the hypotarsus in a lesser degree.

The skeletal plan of the *pes* in *Phalacrocorax* essentially agrees with what we found in the *Anhingidæ*. We are to note the great length of the basal joint of hallux, and for its entire continuity, how much the shaft of the bone is bowed.

Mr. Frederic A. Lucas, Curator of the Department of Comparative Anatomy in the U. S. National Museum, in describing some of the bones of *P. perspicillatus* in the Proceedings of that institution for 1899 (Vol. XII., p. 88), remarked that he had the following material upon which to base his studies, and which had been collected by Dr. Leonard Stejneger on Bering Island in 1882.

"Rostral portion of cranium in advance of the fronto-nasal hinge, with attached palatines.

"Lower mandible.

"Right ramus of lower mandible.

"Two nearly complete sterna.

"Right coracoid.

"Right humerus.

"Left humerus of another individual.

"Right ulna.

"Right fused metacarpals.

"Right fused metacarpals, very imperfect.

"Three pelves, lacking pubic bones.

"Left femur.

"Two left tibiæ.

"Right tibia.

"Two left tarsi.

"Second cervical vertebra.

"Third cervical vertebra.

"Ninth (?) cervical vertebra.

"The more important of these are figured on the accompanying plates, all figures being of natural size, and drawn by the author.

"The bones, although stained, are in a good state of preservation, being but slightly weathered, and all are from thoroughly adult individuals.

"For a better and briefer description of these bones they have been compared with those of an adult *Phalacrocorax carbo,* and the opportunity has been taken to test, to some extent, the value of the subgenera *Urile* and *Phalacrocorax*, by comparing at the same time the corresponding bones of *P. urile* and *P. dilophus.*

"The former bird is, for the species, large and the latter somewhat undersized, although adult.

"The rostrum of *perspicillatus* is nearly as long as in *carbo,* but much more slender, and is readily distinguished from it by the deep, lateral, longitudinal groove characteristic of the subgenus *Urile.*

"The under surface of the rostrum is less grooved, longitudinally, than that of *carbo* and much less so than that of *P. urile* (see Pl. XXIV., Figs. 13–21, and Pl. VI., Figs. 25–28).

"The palatines are as long as those of *carbo*, anteriorly narrow and posteriorly wider, conforming in pattern very nearly to those of *urile*, while *dilophus* resembles *carbo* in this respect.

"The trans-palatine angle is more rounded than in *carbo*, much more than in *urile*, resembling in this *dilophus*.

"The inner portion of the post-palatine is less produced ventrally than in *carbo*, and the pterygoid articulation wider and flatter than in *carbo*, the palatine thus lacking the keel present in *carbo*.

"The same differences are found between the same parts of *urile* and *dilophus*.

"The maxillo-jugal bar is as long as that of *carbo* but more slender.

"The lower mandible is slightly shorter and decidedly weaker than that of *carbo*, and the lower mandible of *urile* is proportionately still weaker than that of *dilophus*.

"The dentary portion of the mandible is more deeply grooved along the inner surface than that of *carbo*, being comparatively the same as in *urile*.

"The cutting edges of the mandible are comparatively straight as in *carbo* and *dilophus*, but *urile* differs from all three in having the mandible distinctly recurved.

"The sternum is transversely flatter than that of *carbo*, being a trifle more flattened even than that of *urile*. The carina is also shorter than in *urile*, but in size and general appearance the sterna of *perspicillatus* and *urile* resemble one another very closely.

"From manubrium to meso-xiphoid that sternum is 13 mm. shorter than that of *carbo*, being exactly as long as that of *urile*.

"The proportion of carina to total length is shorter than in either *carbo* or *urile*, the sternum from anterior end of carina to mesoxiphoid measuring 2 cm. less than that of *carbo* and 4 mm. less than that of *urile*.

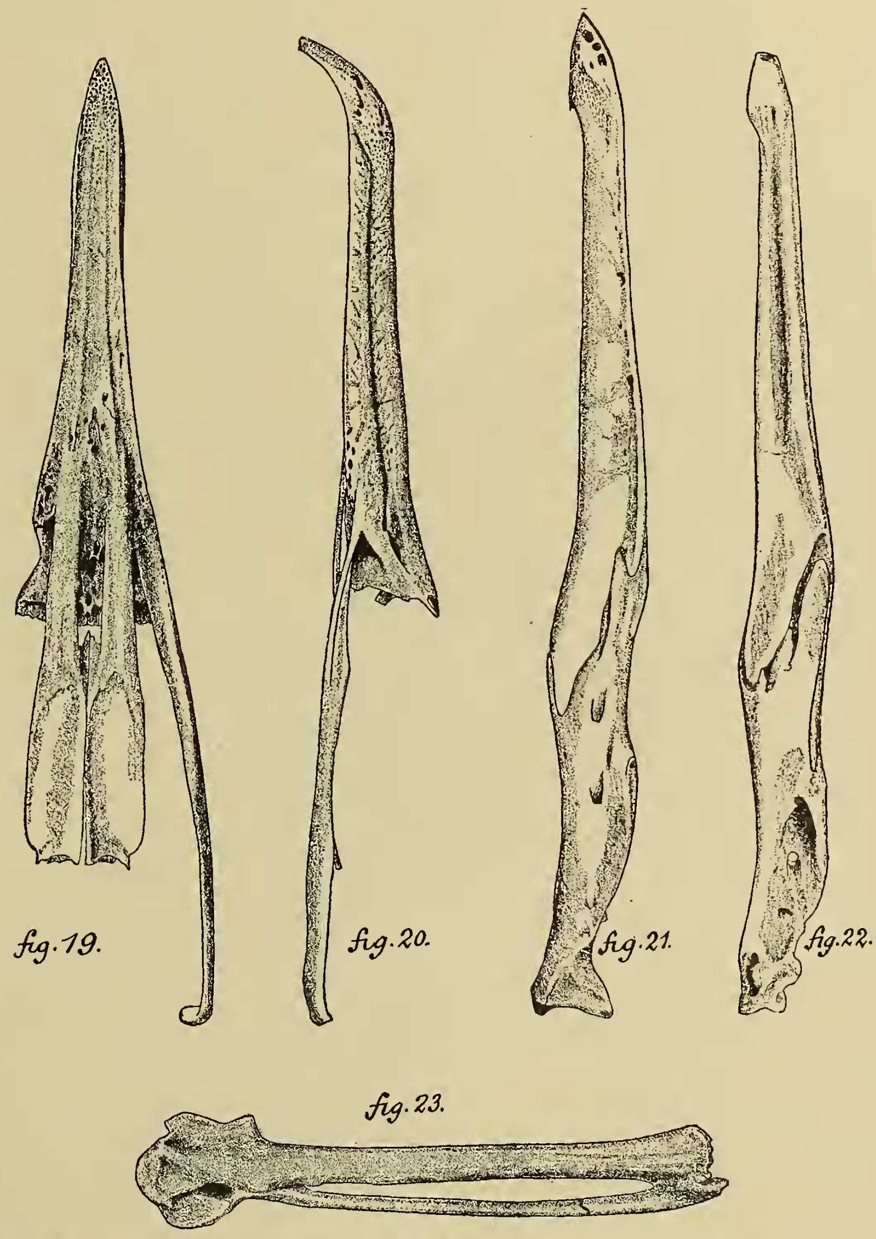
"Between the costal borders the sternum is slightly wider than in either *carbo* or *urile*.

"The rudimentary manubrium, like that of *urile*, lies in the plane of the body of the sternum, while in *carbo* and *dilophus* the manubrium lies in the plane of the keel.

"If a line be drawn between the costal processes it will be found that the coracoid articulations project less beyond this line and form a more obtuse angle with one another than they do in *carbo*, and the same is true of *urile* as compared with *dilophus*. The sternum is non-pneumatic, as in *urile*, but in *carbo* and *dilophus* good-sized foramina pierce its dorsal face just back of the ridge formed by the coracoidal groove.

"It is certainly interesting to find the sterna of these two representatives of the subgenera *Phalacrocorax* and *Urile*, respectively, agreeing with one another in these slight structural points.

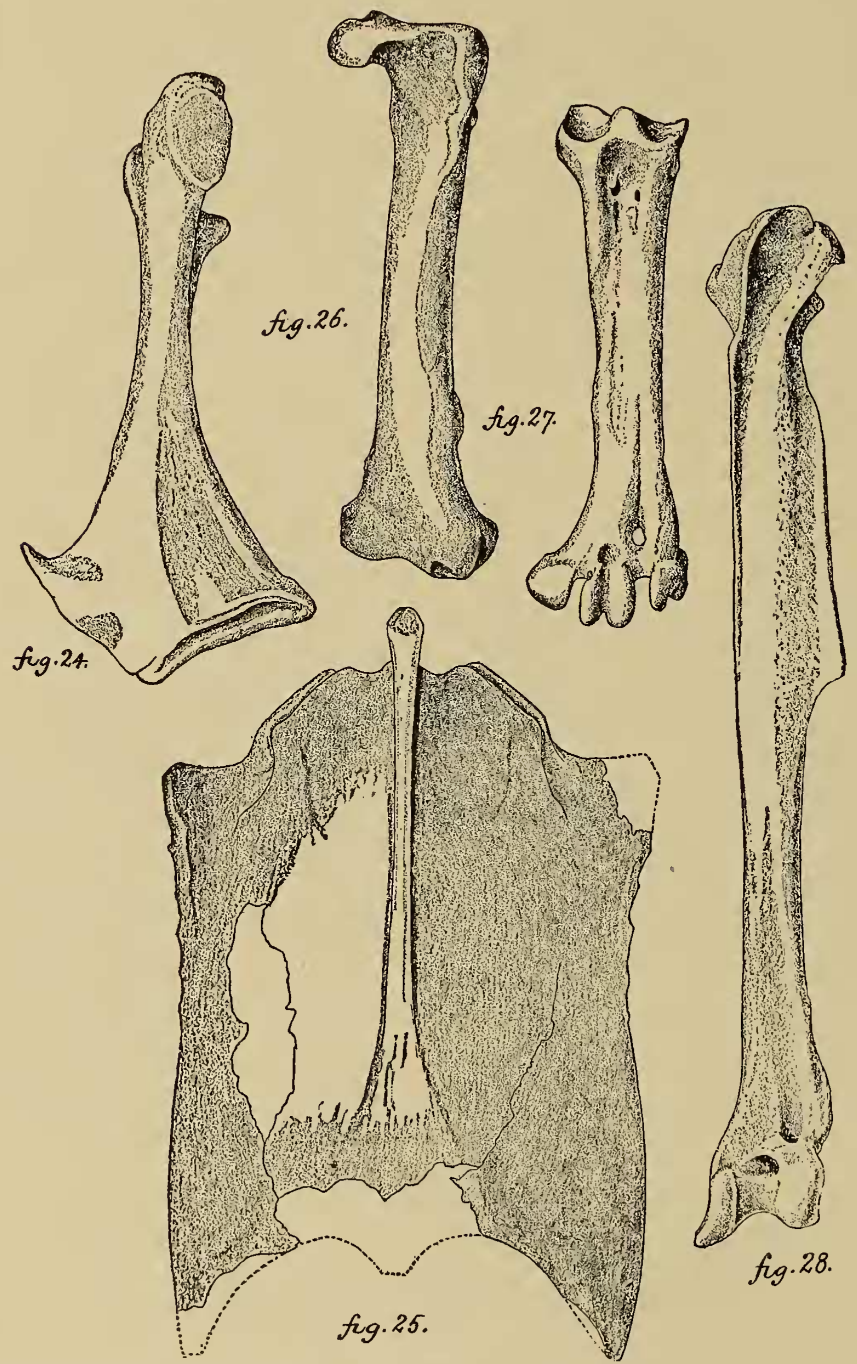
"Articulations are present for five pairs of ribs, the same number as in *carbo*. One specimen of *urile* has four pairs of articulations, another has five on the left side and four on the right, and *dilophus* has but four pairs of costal facets.



Bones of Pallas' Cormorant. Natural size. After Lucas.

FIG. 19. Ventral aspect of rostrum. FIG. 20. Lateral aspect of rostrum. FIG. 21. Right ramus of lower mandible, external aspect. FIG. 22. Right ramus of lower mandible, internal aspect. FIG. 23. Right metacarpals.

"The number of ribs articulating with the sternum is, however, subject to slight variations, especially among water birds, and without an extensive series of specimens it is a little difficult to be sure of the normal number.



Bones of Pallas' Cormorant. Natural size. After Lucas.

FIG. 24. Right coracoid, ventral aspect. FIG. 25. Sternum, ventral aspect. FIG. 26. Femur, anterior aspect. FIG. 27. Tarsus, anterior aspect. FIG. 28. Tibia, anterior aspect.

"The coracoid is of the same length as that of *carbo*, 10 mm. longer than in *urile;* but, while the proximal end is but little heavier than in *carbo*, the shaft and especially the distal end are much more massive.

"The epicoracoid is prolonged upward into a sharper hook than in any of the other species at hand, but this process is subject to considerable variation with age or in various individuals.

"One humerus is a little longer than that of *carbo*, the other is of exactly the same length; both are much stouter, especially in the proximate half.

"The humerus is practically non-pneumatic, the foramina being very minute, while the pneumatic foramina of *carbo*, though not large, are readily seen.

"The humerus of *urile* differs from that of *dilophus* precisely as that of *perspicillatus* from *carbo*.

"The ulna is distinguishable from that of *carbo* only by its greater weight, and the same may be said of the humerus of *urile* as compared with that of *dilophus*.

"The fused metacarpals are slightly shorter and slightly stouter than in *carbo*, and here again the same differences are observable between the metacarpals of *urile* and *dilophus*.

"The 'sacrum,' as a whole, is as long as that of *carbo*, but its component parts are more heavily built.

"It comprises six pre-sacrals, two true sacrals, and nine post-sacrals, and the three 'sacra' of *perspicillatus* agree with one another in these particulars.

"*Phalacrocorax carbo* has six pre-sacrals, two true sacrals, and nine or ten post-sacrals. *P. urile* has six, two, eight, and *dilophus* six, two, nine.

"The hypapophyses of the anterior three vertebræ have been broken off, but although the compressed centra are larger than in *carbo*, the hypapophyses seem to have been smaller.

"The six pre-sacrals present few salient characters, but the diapophyses of the fourth vertebra lie at right angles to the vertebral column, while in the three other species the diapophyses of this vertebra are directed forward.

"The sacral and immediate post-sacral vertebræ vary in the development of their parapophyses in all four species under consideration.

"In all three specimens of *perspicillatus* the two true sacrals bear no parapophyses, while the two succeeding vertebræ have them extended to, and anchylosed with, the ilium.

"The diapophyses and parapophyses of these vertebræ are united by a thin plate of bone, but that this is due to age is shown by the condition obtaining in the other species.

"These latter also indicate that the canal formed by these processes, the centra of their vertebræ and the ilium, is larger on the right side than on the left, and that it is the first obliterated on the left side.

"In *carbo* neither the sacrals nor the second post-sacral bear parapophyses, although these are present on the first post-sacral, uniting it firmly with the ilium.

"In one example of *urile*, slender, but well-marked parapophyses connect the two sacrals with the ilia.

"In another and much smaller specimen the second sacral has a parapophysis on the left side, there being no parapophyses on the first sacral.

"In both specimens of *urile* the first, but not the second, post-sacral bears parapophyses. Finally, *dilophus* has strong parapophyses on the second sacral and first post-sacral, but none on the second post-sacral.

"The variation in the sacral region of these specimens is not only interesting in itself, but interesting from the fact that it is unusual for parapophyses to be present at all on the true sacral vertebræ of birds.

"Viewed from above the ridge formed by the confluent spinous processes of the 'sacrals' is wider than in *carbo*, and the interpophysial foramina are nearly closed, while in *carbo* they are very open.

"Although these characters depend to some extent on age, they do not entirely, and the same differences exists between the 'sacra' of *urile* and *dilophus* as between those of *perspicillatus* and *carbo*.

"The pelvis is much more rugose than in *carbo*, all attachments for muscles being strongly emphasized.

"The anti-trochanter is placed further back than in *carbo*, and is much more rounded, thus affording more play to the femur.

"Just back of the anti-trochanter the outer edge of the ilium is raised and thickened, forming a flat, subtriangular spot, but proportionately smaller than in *perspicillatus*.

"Back of this flattened portion the dorsal edge of the ilium is bent outward, making this part of the ilium outwardly concave, where in *carbo* it is convex.

"The post-ilia of *carbo* and *dilophus* round gently outward and downward throughout their entire length from their junction with the diapophyses.

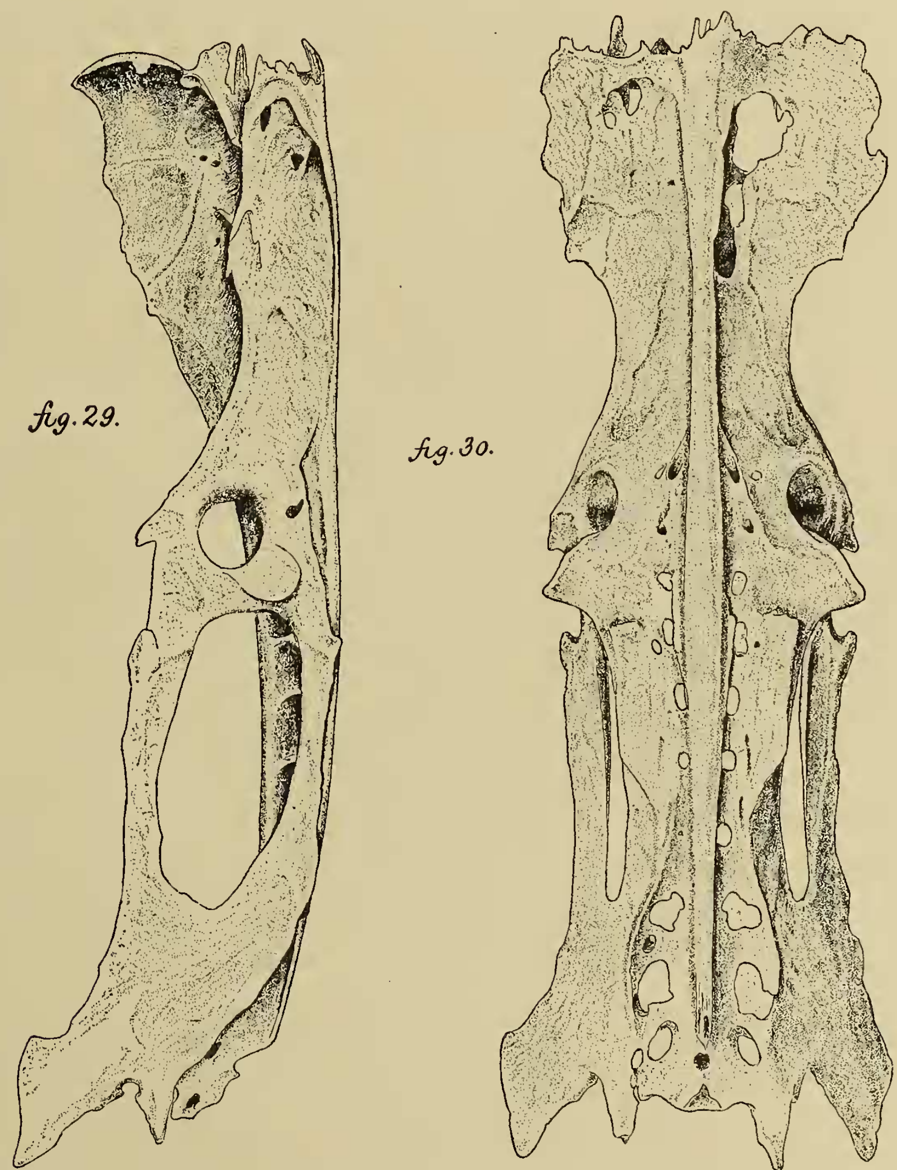
"Viewed from the side the dorsal outline of the 'sacrum' is slightly decurved, while that of *carbo* is very nearly straight and the same difference exists between *urile* and *dilophus*.

"The acetabulum is slightly larger and forms more nearly a perfect circle than in *carbo*.

"The ilio-ischiatic foramen is subelliptical and wide, the longitudinal diameter being nearly twice the vertical, while in *carbo* this foramen is more pointed posteriorly and narrower, the length being more than three times the height.

"In consequence of the size of this foramen the distance from the dorsal edge of the ilium to the ventral edge of the ischium is much greater than in *carbo*.

"The bar of the ischium bounding the obturator space is sharp-edged, rugose, and concave exteriorly on the posterior portion, while the corresponding portion of the ischium in *carbo* is comparatively smooth and slightly convex posteriorly.



Bones of Pallas' Cormorant. Natural size. After Lucas. FIG. 29. Left lateral aspect of pelvis. FIG. 30. Dorsal aspect of pelvis. The long, sweeping post-pubic bone was broken off and lost from this bone when it was discovered.

"The posterior border of the ischium is straighter than in *carbo* and the ilio-pubic articulation one third shorter.

"The femur is 5 mm. longer than that of *carbo*, in every way much more massive, and with all the muscular ridges more pronounced, while curiously enough it is more pneumatic, having several foramina in the ventral aspect of the neck that are lacking in *carbo*.

"There is nothing to distinguish the femur of *urile* from one of *dilophus* of the same length, and of the two that of *dilophus* is slightly the heavier.

"But in the specimen of *urile* in which the humerus corresponds in length to that of *dilophus*, the femur and tibia are both longer and heavier than in *dilophus*, and the tarsus a little lighter.

"The phalanges, again, are more massive in *urile* than in *dilophus*.

"The smallest of the three tibiæ is slightly longer than that of *carbo*, the cnemial crest is more expanded, and the cnemial ridges farther apart and more pronounced.

"The distal extremity of the tibia is also wider than in *carbo*, but at its smallest diameter the shaft is no larger.

"The muscular ridges and grooves are more marked than in *carbo*, but in the absence of more material and making due allowance for individual variation, it is difficult to point out characters which definitely distinguish the tibiæ of the two birds.

"The tarsus is of the same length as in *carbo*, but much wider, and, as throughout, with all the ridges more pronounced.

"Little can be said concerning the three cervical vertebræ, except that, unlike the other bones, they are less strongly built than the corresponding bones in *carbo*.

"From the foregoing notes it will be seen that the differences existing between corresponding bones of *perspicillatus* and *carbo* also exist between the same bones of *urile* and *dilophus*, and that conversely *perspicillatus* and *urile* agree with one another as do *carbo* and *dilophus*.

"The subgenera *Phalacrocorax* and *Urile*, therefore, seem to rest on good structural foundations, each being characterized by internal as well as external characters.

"Unfortunately no skull of *perspicillatus* is to be had, but the crania of *carbo* and *dilophus* agree with one another, while differing strikingly from the cranium of *urile*.

"From the harmony of the other parts its not assuming too much to suppose that the skull of *perspicillatus* would resemble that of *urile*."

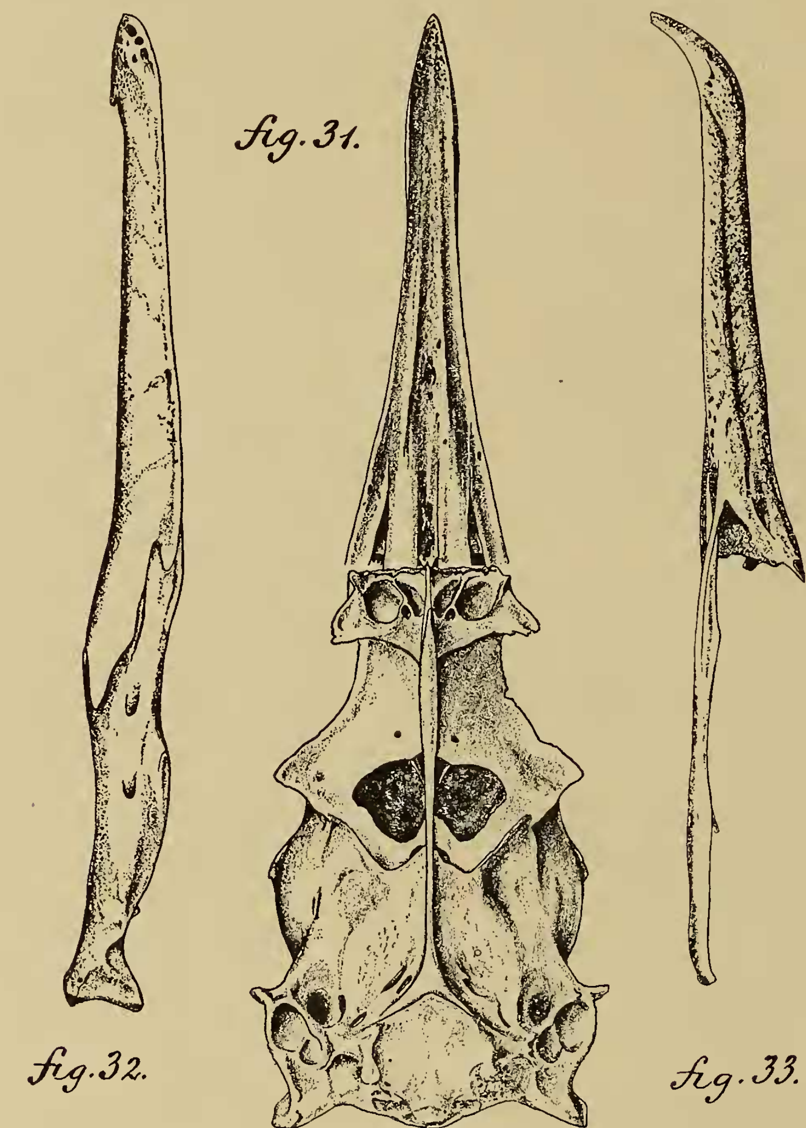
"With the exception of the sternum the greater size of the bones distinguishes those of *perspicillatus* from those of *urile*, while well-marked differences of shape or proportion exist between the corresponding bones of *perspicillatus* and *carbo*.

MEASUREMENTS (IN MILLIMETERS) OF CORRESPONDING BONES OF PHALACROCORAX PERSPICILLATUS, CARBO, URILE, AND DILOPHUS. [FROM LUCAS.]

(*All measurements are in a direct line and not along curves.*)

	P. perspicillatus (National Museum, 17041).	*P. carbo* (Yale College Museum, 535).	*P. urile* (National Museum, 12502).	*P. dilophus* (National Museum, 18050).
Rostrum:				
Tip of mandible to extremity of maxillo-jugal bar	134	140	108	105
Maxillo-jugal bar	68	69	56	56
Tip of mandible to posterior end of palatine	109	117	91	86
Width across nasals, at fronto-nasal hinge	21	20	13	14
Lower mandible:				
Length of ramus	139	144	112	110
Greatest height of ramus	13	13	9	12
Sternum:				
Anterior end of carina to mesoxiphoid	104	119	97	91
Manubrium to mesoxiphoid	83	97	84	76
Depth of carina	28	33	31	26
Width across articulations of first rib	64	66	64	54
Width across articulations of fourth rib	63	59	60	51
Coracoid:				
Length	84	87	71	70
Breadth of sternal articulation	25	25	24	20
Greatest distal breadth	18	17	16	13
Humerus:				
Length	170	170	140	140
Greatest proximal breadth	30	28	25	23
Greatest diameter of shaft midway between extremities	11	9	10	8
Greatest distal breadth	21	20	18	17
Ulna:				
Length	190	178		
Greatest proximal breadth	21	18		
Greatest diameter of shaft midway between extremities	8	7		
Pelvis:				
Greatest length of ilium	151	152	122	120
From anterior border of ilium to external angle of anti-trochanter	72	65	58	49
Greatest width of ilia in advance of acetabula	48	44	42	38
Least width of ilia in advance of acetabula	23	23+	19	18
Width between outer extremities of anti-trochanters	43	46	37	33
Length of ilio-ischiatic space	42	41	32	38
Greatest width of ilio-ischiatic space	18	13	13	10
From dorsal edge of ilium, above the ilio-ischiatic foramen, to ventral edge of ischium	28	23	23	19
Length of ilio-pubic articulation	21	28	15+	23
Between posterior terminations of ischia	46	40	42	40
Femur:				
Length	74	70	66	55
Greatest proximal width	21	19	16	15
Greatest diameter midway between extremities	11	10	9	8
Greatest distal width	22	18	16	15+
Tibia:				
Length	140	127	117	102
Width across cnemial ridges	15	13	11	11
Width at distal end of articulation with fibula	15	13	11	13
Least transverse diameter of shaft	8	8	7	7
Distal width	16	15	12	13
"Tarsus":				
Length	71	72	60	62
Proximal transverse width	19	16	14	14
Distal width	20	18	15	14

" *P. perspicillatus* appears to have been a much heavier bird than *carbo*, and a bird of weaker flight; with more robust and muscular legs, and a more slender and more feeble head and neck.



Skull and Jaw-bones of Pallas' Cormorant. (After Lucas.)

FIG. 31. *Phalocrocorax perspicillatus*, inferior aspect of cranium. The anterior and posterior portions are from different individuals. (Nat. size.)

FIG. 32. *Phalacrocorax perspicillatus*, left ramus of jaw, external aspect. (Nat. size.)

FIG. 33. *Phalacrocorax perspicillatus*, mandible and left palatine, external aspect. (Nat. size.)

" In comparing the tables of measurements it must be said that they do not adequately convey the impression produced by a comparison of the bones themselves. Thus, in the measurements of the lower mandible the greatest vertical width is comparatively as in *carbo*, but from this point the ramus tapers rapidly either way so that, as a whole, the mandible is much weaker than that of *carbo*.

"So too with the humerus, where the greatest proximal width is only 2 mm. greater than in *carbo*, although the bone in its entirety is much more stoutly built."

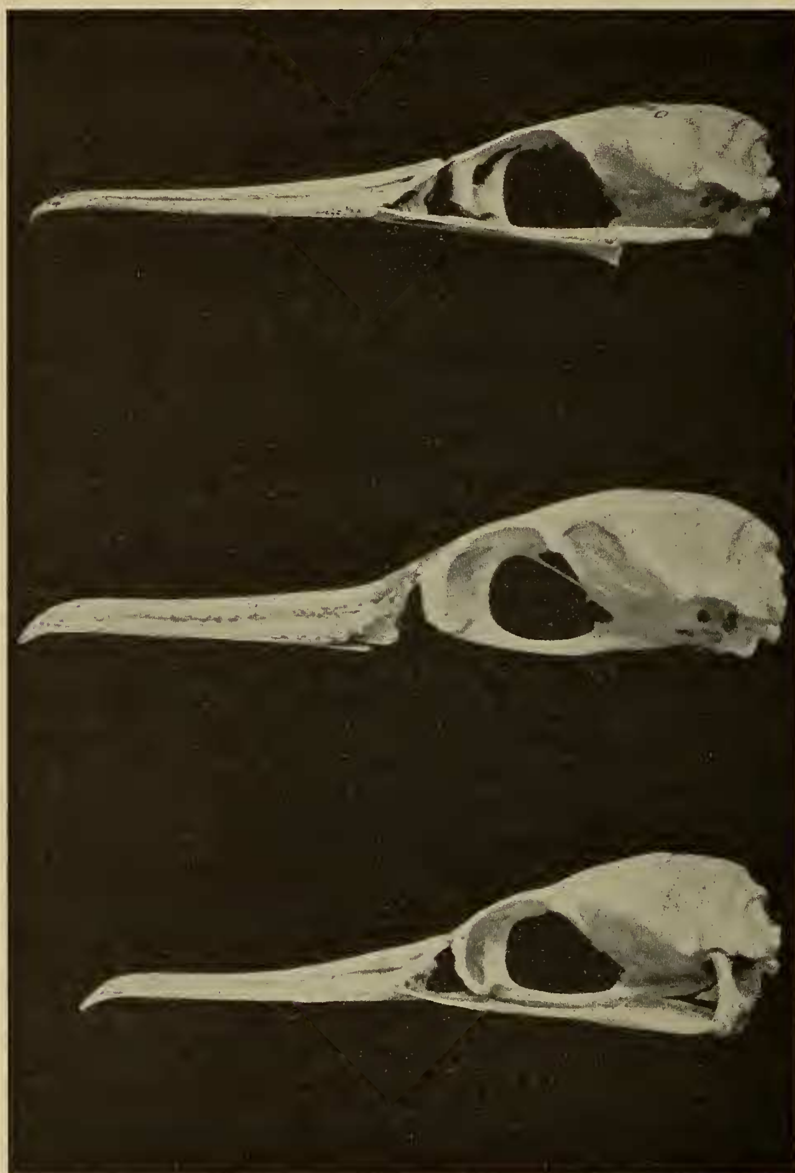
In a following volume of the Proceedings of the U. S. National Museum, in which Mr. Lucas described the above specimens of bones of *P. perspicillatus*, he on subsequent pages also described the skull of this species, and presented other data of importance having reference to the *Phalacrocoracidæ* (Vol. XVIII., pp. 717–719, Pls. XXXIV.–XXXV.).

This second lot of bones were likewise obtained by Dr. Stejneger at Bering Island in 1895, or thirteen years after the first specimens were collected by him. A cranium and a sternum of *P. perspicillatus* are found in this second installment, and they are very important discoveries.

The cranium is now in the collection of the Museum (No. 19417, U. S. N. M.). "In its general contour," says Mr. Lucas in his paper referred to above, "it most closely resembles that of *P. penicillatus* among existing cormorants, but is decidedly larger, and is proportionately wider than in that species, while the beak is shorter. As far as mere size is concerned, the skull of an adult male of *P. carbo* would be as long as that of *P. perspicillatus*, but the latter is much wider and is more depressed. The cranium is readily distinguished from that of *P. urile* by its greater size and less depression, and by having a proportionately stouter beak, whose ridge lacks the slight but characteristic emargination found near the base of the beak in *P. urile*.

"As a matter of fact, the differentiation of cormorants into species with grooved beaks and those without does not exist, so far as the bony beak is concerned. Some have deeper grooves than others, but all have more or less of a furrow along the side of the mandible, and there is every degree of gradation, from such well-furrowed beaks as those of *P. albiventris* and *P. magellanicus* to the shallow grooves of *P. melanoleucus* and *P. carbo*.

" Pallas's Cormorant shows a marked difference from all others examined in the development of the lateral ethmoid. In other species the lachrymal sends a process inward which fuses with a spur from the mesethmoid to form a more or less L-shaped bar of bone, uniting the frontal and mesethmoid. A small spur, arising from the inferior inner angle thus formed, represents the lateral ethmoid, and this is usually but little developed, being largest in *P. penicillatus* and obsolete in *P. urile*. In *P. perspicillatus* there is a lateral ethmoid plate, complete save for an opening above, being the retention by ossification of a cartilaginous plate found in the nestling of *P. urile* before the nostrils have become closed. The maxillopalatines are also slightly better developed than in any existing cormorant, and while the difference is small, still it does exist, and here again it is seen by comparison to be the development of a character found in young birds.



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Crania of various Cormorants. (After Lucas.)
FIG. 34. *Phalacocorax penicillatus.*
FIG. 35. *Phalacrocorax perspicillatus.*
FIG. 36. *Phalacrocorax carbo.* (Two thirds natural size ; from photographs.)

" Difference exist between *P. perspicillatus* and other cormorants by the presence of a narrow bar of bone forming two precranial cavities where but a single opening exists in allied species, and in the comparatively small size and regular lyrate form of these openings. From these conditions it will be seen that there is in the cranium an excess of ossification over that found in other cormorants. While no bar of bone has been found in other species, there are hints of it in some, thus, *P. penicillatus* and *P. magellanicus*, in the shape of a little bony spike running upward from the alisphenoids, and it is not impossible that the complete bar may be found in some very old individual. This is the more probable because in the young, of *P. urile* at least, there is a bar of cartilage occupying the place of the bar of bone found in Pallas' Cormorant.

MEASUREMENTS[13] OF SPECIES OF PHALACROCORAX.[14] [FROM LUCAS.]

STERNUM.

	P. perspicillatus, male (U. S. N. M., No. 19417).	*P. carbo*, male (Yale College, No. 535).	*P. penicillatus* (U. S. N. M., No. 18535).	*P. urile*, male (U. S. N. M., No. 12502).
	mm.	*mm.*	*mm.*	*mm.*
Anterior end of carina to mesoxiphoid	132[15]	119	101	104
Manubrium to mesoxiphoid	109	97	87	90
Depth of carina	40[15]	33	22	25
Width across articulations of first rib	84	66	60	70
Width across articulations of fourth rib	72	59	58	65

SKULL.

	P. perspicillatus, male (U. S. N. M., No. 19417).	*P. carbo*, male (U. S. N. M., No. 18851).	*P. penicillatus* (U. S. N. M., No. 940).	*P. urile*, male (U. S. N. M., No. 12502).
	mm.	*mm.*	*mm.*	*mm.*
Tip of mandible to occipital condyle	148[16]	135	141	116
Fronto-nasal hinge to articulation for occipital style	69	61	62	55
Across anterior part of frontals	22	20	19	13
Across postorbital processes	39	31	32	25
Across squamosal processes	45	36	37	32
Across exoccipital processes	40	33	33	26

"The sternum (No. 19417, U. S. N. M.) found with the present series of bones is important, as its size indicates it to be that of a male, and shows the sternum previously described to have been that of a female, or possibly even that of a male of *P. urile.* It is very much larger than any sternum of *P. urile*, and much larger even than the large specimen of *P. carbo*, used for comparison.[17] The present sternum is

[13] The measurements are in a straight line.

[14] Proc. U. S. Nat. Mus., XII., 1889, p. 88.

[15] Estimated, owing to breakage.

[16] Taken from rostrum of one bird and calvarium of another.

[17] Proc. U. S. Nat. Mus., XII., 1889, pp. 88-94.

thus in harmony with the other bones, and aids materially in emphasizing the superior size of *P. perspicillatus*.

"The appended tables give the measurements of the cranium and sternum here described, compared with the corresponding parts of other species. The measurements of the previously described sternum, ascribed to *P. perspicillatus*, are repeated and an error of the first-given table corrected. The length from anterior end of carina to end of mesoxiphoid is said to be 104 mm., when it should have been 90 mm.

Unfortunately the skull of *P. carbo* now available is smaller than that of the individual used as a term of comparison in the previous paper[18] on Pallas' Cormorant."

Additional information in regard to the osteology of the *Phalacrocoracidæ* will be found further on in the present memoir, as well as under the explanation of the plates at its close.

Osteology of the Pelecanidæ.

(Plate XXVII., Figs. 31–41; Plate XXVIII., Fig. 42, and Plate XXX., Fig. 49.)

Sometime during the year 1864, the writer collected on Indian Cay of the Bahama Banks, a fine adult male specimen of *Pelecanus fuscus*. From it I took the skull, and have it before me at the present writing.

Measuring from the transverse cranio-facial groove we find the osseous superior mandible in this specimen to be somewhat less than four times as long as the remaining part of the skull. A vertical section made through the middle of the posterior third of this mandible at right angles to its long axis gives an elliptical figure, with the minor axis in the horizontal plane. The anterior two thirds has a sharp lateral edge, while the extremity is armed with a powerful decurved hook. About half of the fore part of this enormous beak is compressed from above downward, a compression that is accompanied by a gradual widening of the bone to near the end, where it slopes in toward the hook in the median line.

The maxillo-palatines constitute a great spongy mass that fills up a space anterior to the rhinal chamber. They unite in the median line, are bounded above by the premaxillary, below by the united palatines, while the anterior extremity of the maxillary fuses with the mass at about its middle on either side. (Compare with Figure 36, Plate XXVII.)

In form this maxillo-palatine mass is wedge-shaped, with the broad end anchylosed with the under side of the united nasal processes of the premaxillary.

[18] *Loc. cit.*

Posteriorly its wall is composed of compact tissue, being at right angles to the longitudinal axis of the skull. It slants from the under side of the cranio-facial hinge to the anterior margin of a median foramen, seen just anterior to the keel which is formed by the union of the palatines behind.

This posterior maxillo-palatine wall has a cleft in its lower two thirds, while two conical pits, placed side by side, lined with compact osseous tissue, occupy its upper third. They have their bases opening in the rhinal chamber, and their apices are pierced by the small subcircular nostrils, one in each conical passage.

The hinder half of the jugal bar is compressed from side to side, slightly dilated, with its end crooked up, and in life simply bound to the upper and outer side of the quadrate.

The body of a *lacrymal* fuses completely with the cranial elements above, its upper surface assisting in forming the smooth superfices of the frontal region. This is also the case in *P. sharpei* (Pl. XXVII., Fig. 37). From this portion it sends downward and slightly backward a descending process. This is composed of a cylindrical pedicel for its upper third and an antero-posteriorly compressed portion for the lower two thirds. It fails to reach the maxillary, its tip remaining free just above that perpendicularly compressed bar which passes immediately beneath it.

The interorbital septum is entire, with the exception of a semicircular perforation, which is immediately in front of the aperture in the anterior wall of the braincase that gives egress to the optic nerves.

Each olfactory has a small foramen in either orbit at its usual site; the track for the nerve being a broad, shallow groove beneath the orbital vault.

The *mesethmoid* is very deep; its anterior border is sharp and thin. Commencing in the aperture of the angle between the pterygoidal shafts, it is carried directly upward and forward to the expanded portion beneath the roof of the cranio-facial region, the edge meeting the median division of the maxillo-palatines. (For figures illustrating the skull of the Brown Pelican see my memoir on the "Osteology of the Tubinares and Steganopodes," Proceedings U. S. Nat. Museum, 1888, Vol. II., pp. 311–315.)

The lower fourth of this ethmoidal border is thickened and rounded for the articulation of the palatine and pterygoidal heads.

Coming, as usual, from the anterior apex of the basi-temporal triangle, the other portion of the rostrum is decurved and meets the point referred to above in the angle between the pterygoids,

A *quadrate* is a very large bone with a broad, triangular process. Its mastoidal head can hardly be said to be divided into two, as in most birds, for the division is so very slight and faintly marked; and a large pneumatic foramen is seen upon its outer side — a very unusual place for this aperture.

Its mandibular foot is narrow antero-posteriorly and very wide transversely. Two facets occupy its lower surface, separated from each other by a concave notch which is deepest anteriorly.

The bone also presents a smooth articular surface for the quadrato-jugal at the point above mentioned, while a large convex facet is offered to the pterygoidal cup of the pterygoid of the corresponding side.

We find the external openings to the ear to be very small, and hid from sight upon direct lateral view by the quadrate. A sphenotic process is well developed, but the mastoidal one is simply a roughened line; between the two is a wide crotaphyte valley leading from the fossa of the same name, which is here small, inconspicuous, and entirely lateral.

The orbital cavity itself is thus seen to be deep and capacious, lacking bony walls principally upon its inferior and anterior aspects. They are more complete in *P. sharpei* (Pl. XXVII., Fig. 37).

Upon its under side this skull presents a number of points of interest. The anterior moiety of the superior mandible is here seen to be longitudinally grooved by a broad and shallow furrow, which gradually becomes somewhat narrower as we proceed backward, to finally merge into the convex median portion of the hinder half of this great rostrum. Along its median line it is marked by a few scattered, slit-like foramina that lead into its shallow interior, which latter is largely filled with an open mass of spongy, osseous tissue, continuous with the maxillo-palatines behind.

The palatine bodies, including their heads, fuse together for their entire extent in the median plane. Resulting from this union we have a single, descending, median carination, composed of the united inner keels of the palatine bodies and a similar superior median one composed of the ascending processes of the same.

The latter is truncated just before reaching the maxillo-palatine bodies.

This skull lacks basi-pterygoid processes, while the pterygoids themselves are short, thick set bones, with large anterior and posterior heads, and sharpened longitudinal crests on the superior aspects of their shafts.

The basi-temporal triangle is small and its area concave. A thin, pointed lip of bone eaves over the entrance to the Eustachian tubes, which are here apparently thoroughly surrounded by bony walls.

We find the foramen magnum situated at the bottom of a broad, deep, and transverse concavity. This excavation is bounded on either side by the dome-like mastoid prominences, in front by the line of the base of the basi-temporal triangle, and behind by a low, smooth ridge which arches between its lateral boundaries. The foramen magnum cannot be seen on a direct vertical view of the base of the skull (Pl. XXVII., Figs. 35 and 36).

The occipital condyle is rather large, ellipsoidal in form, and placed transversely, while the outline of the foramen is also a broad ellipse, but with its long axis placed just the other way. The plane passing through its periphery makes an angle with the plane of the basis cranii of about sixty degrees.

Regarding this skull from a superior aspect we are to note the small, subcircular openings to the nostrils, situated a little beyond the irregular line marking the cranio-facial hinge (Pl. XXVII., Fig. 40).

Their centers are about 2 mm. apart, and each one is situated at the posterior end of a groove. These grooves extend the entire length of the superior mandible, passing out on either side of the hook at its anterior extremity. At first each is rather on the lateral aspect of the bone, but beyond the posterior half they gradually converge and get on top, to include between them the prominent convex culmen. Just before reaching the hook, however, the included surface becomes flat and depressed, when the lines terminate, as pointed out above.

The top of the skull in this Pelican is very flat for the frontal region, being simply curved downward at the outer borders. As we proceed backward to the parietal region, however, it gradually becomes more convex and dome-like, though still retaining its absolutely smooth and polished character. This latter may also be seen from a posterior aspect, and below it the high, arching, and equally smooth occipital area. This latter extends down on either side over the enormous mastoidal elevations of this bird. We also notice that from this view we may see directly into the foramen magnum; the entire pterygoids are in sight, and the quadrates come down far below the basi-cranial plane.

The *mandible* from the skeleton of this Pelican is represented by a long, narrow loop of bone, which is strikingly devoid of prominent characters. Its symphysis is very short and decurved, being slightly excavated on its superior aspect behind (Pl. XXVII., Fig. 41).

The upper and lower margins of either ramus are rounded for their entire length, while the sides included between them become gradually narrower as we proceed in the direction of the symphysis. These are smooth both internally and externally and both concave in the vertical direction.

Rather more than the posterior moiety of each ramus is hollow for the admission of air, and each presents two foramina, which seem to be intended for that purpose. One of these is on the inner and upper aspect of the ramal shaft, just beyond a concavity that occurs immediately anterior to the articular cup. The other, elliptical in form, is on the inner and lower aspect, and about 2 cm. beyond it.

Each articular cup presents two concavities—a central one and another occupying the inturned process of this extremity. Both have pneumatic foramina at their bases. The mandibular angle behind is truncate and much compressed in the perpendicular direction. The under surface of one of these ends is perfectly smooth and gradually merges into the inner and outer surface of the ramal shaft. Almost complete disappearance of the coronoids has taken place.

Almost the entire skull of this bird is highly pneumatic, and I have carefully compared it with the specimen loaned me by the U. S. National Museum, and find that they agree in all essential particulars. In the latter I find a mandible 38 cm. long, while the symphysis of the same only measures 4 mm. The superior carination of the united palatines is somewhat higher, especially in front than in my own specimen, but I am inclined to believe that in mine the free margin has somewhat broken off, and due allowance should be made for it in the figure illustrating the skull of this bird in my earlier memoir (Fig. 40) showing the lateral view of the Pelican's skull, when the supero-median palatal keel is drawn a little too low.

Fig. 20 of Huxley's 1867 paper in the P. Z. S. is a good representation of the posterior half of the skull of a pelican (*P. onocrotalus*) seen upon its basal aspect. The side view of the same is very indifferently drawn.

Some few of the small bones of the disarticulated National Museum specimen at my hand may have been lost, but none of any consequence. Almost the entire skeleton is pneumatic, and exceedingly light. The pygostyle is as light as a wafer, and taken with all the caudal vertebræ, only weighs a few grains. Among the non-pneumatic bones we note the atlas, the fibulæ, the first metatarsal, and all the toe-joints. Some of the bones are actually riddled with air-holes, and such a long bone as the humerus has many minute foramina at very various localities at both of its extremities. The pelvis weighs no more than were it made of cork, and so it is with all the other large bones.

Of the Remainder of the Axial Skeleton in Pelecanus.

(See Plate XXVII., Figs. 31–34, 38, 39; Pl. XXVIII., Fig. 42, and Pl. XXX., Fig. 49.)

Professor Mivart found in the spinal column of a specimen of *Pelecanus mitratus* in the British Museum but "forty vertebræ in all, there being but three lumbar and five caudal"; and in a specimen of *P. onocrotalus* (No. 527A), forty one vertebræ, there being but three sacro-caudals. He says, however, that in this species the general number seems to be forty-two vertebræ in all, not counting the pygostyle.

In a complete skeleton of *Pelecanus fuscus* before me (No. 18483), I find sixteen true cervical vertebræ, none of which support true ribs. The seventeenth bears a pair of large, well-developed ribs which do not connect with the sternum, and which have long epipleural appendages low down on their shafts, where they are anchylosed. The eighteenth vertebra is the ultimate one of the dorso-cervical series of the spinal column that is free. Its ribs are broad and flat, with their appendages coössified to the shafts at an angle of 45°, and inclined to be slender, narrow, and pointed.

The nineteenth, twentieth, and twenty-first vertebræ are not only all fused together, but are similarly joined with the bones forming the pelvic "sacrum." This union is most perfect, and is considerably fortified by the complete coössification of the metapophyses extending between the extremities of the transverse processes, and then with anterior iliac borders, in which location the ossifying process has been extended quite across, thus, on superior aspect, shutting the twenty-first vertebra out from view.

These three vertebræ also bear broad and flat ribs, connecting with the sternum as do all the thoracic ribs in this Pelican. This pair belonging to the nineteenth vertebra are quite like those described above for the eighteenth; they are broader, however, which is also the case with the pair suspended from the twentieth vertebra. These last have the epipleural spines reduced in size, while the last two pairs of ribs, or those belonging to the twenty-first vertebra, and the pair of "pelvic ribs" lack these appendages entirely.

Almost completely pneumatic in character, the leading *costal ribs* are rather short, but the series gradually increases in length as we pass backwards, all of them being more or less pneumatic, and all being remarkable for having their extremities enlarged, for the purpose of affording a greater articulatory surface at those points. For the most part, the pneumatic foramina in these hæmapophyses are to be found at their sternal ends.

The free pelvic vertebræ all have a swelled appearance, while their surfaces are as a rule smooth, their salient angles much rounded off, and their processes quite subordinated.

The cup of the *atlas* is deeply notched above, as is the articular surface of the body behind, concaved upon the same aspect. This surface is of an elongo-reniform outline, its transverse diameter being of the greatest length. A small hypopophysial tip extends backwards from its mid-point below.

Not especially stout, the lateral pedicels support a broad, oblong neural arch, which has a straight anterior, and a concave posterior margin. Air gains access to this vertebra through some holes situated in or near a small concavity, over which articulates the ventral surface of the odontoid process of the axis when the bones are *in situ*. A polishing of the surface alone indicates the points where the anterior margin of the neural arch comes in contact with the occipital bone of the cranium, and where the ventral aspect of its posterior margin rides on the upper part of the anterior margin of the neural canal of the axis.

A broad-based, swollen, and tuberous neural spine is one of the chief characters of the last-named vertebra, while its hæmal spine, situated posteriorly on the centrum, is transversely compressed, sharp along its infero-mesial border, and withal rather inconspicuous.

The articular surface on the body for the atlas is deeply concave, and always presents a large mesial pneumatic foramen at its base, just beneath the odontoid process. Posteriorly, the neural arch of this vertebra far overhangs the centrum below, while either postzygapophysial portion of it, not strictly defined from the bone, has upon its direct ventral aspect a large oval articular facet for articulation with the corresponding ones at the prezygapophyses of the third vertebra.

We have no lateral canals in the axis vertebra of this Pelican, but a small pneumatic foramen is usually seen on either side, at the site of their occurrence in the next bone of the spine behind it, at points where they open posteriorly. In the third, fourth, fifth and sixth vertebræ the neural spine is represented by a low, lengthy, and thickened ridge, which fails in any case to reach the dorsal margins of the neural canal, either in front or behind. In the seventh vertebra the neural spine is much restricted, occupying only the center of the bone. It begins to disappear in the eighth ; is almost absent in the ninth and tenth ; feebly reappears in the eleventh and twelth; begins to be tuberous in the thirteenth ; and from this on it slowly assumes the form it has in the dorsal series, where it is low, thickened, and wedge-shaped, with base behind and apex in front.

Far back on the centrum of the third vertebra we find a short, thick, and low hæmal process ; somewhat resembling the one on the axis. The character is quite obliterated in the fourth vertebra, where we begin to see, anteriorly beneath the extreme fore part of the centrum, the first indications of the formation of the carotid passage. They are more distinct in the fifth vertebra ; still more so in the sixth ; decidedly so in the seventh, where the remarkable peculiarity exists in that a carotid channel with thin, conspicuous side-walls abruptly develops at the extreme hinder end of the centrum. This character is just as well marked in the eighth vertebra, after which it gradually disappears (never to form a completed tube), to be gone entirely in the thirteenth cervical.

In the eighth vertebra the anterior part of the carotid passage is a solid, closed tube, its parapophysial walls being thick and strong, the passage of considerable caliber, and the whole occupying more than the anterior third of the ventral aspect of the bone. It also shows, ventrad, a mid-longitudinal ridge, with a longitudinal gutter upon either side of it. This carotid canal remains a closed tube to include the fourteenth vertebra, slowly changing in character as we near the dorsal series. In the fifteenth to the seventeenth inclusive, its place is taken by a well-marked hæmal spine—a character entirely absent in the eighteenth vertebra, which is a true dorsal one.

No evidence of a hæmal spine whatever exists in the three fused dorsal vertebræ, and in them the neural spine is but represented by a coössified, flattened ridge, hardly at all higher than the fused metapophysial track at the ends of the diapophyses, on either hand. Lateral canals begin in the third vertebra and persist to the sixteenth inclusive. They are long and of small caliber in the third, fourth, fifth and sixth, materially shortened in the seventh; somewhat more so in the eighth, where, for the first time, their anterior opening looks directly dorsad, which latter continues to be the case in the ninth, tenth, eleventh, twelfth, thirteenth and fourteenth, the canals increasing in caliber, but at the same time shortening in length as we pass through the series just named. In the fifteenth and sixteenth vertebræ, the lateral canals are parallel with the neural canal, about one third smaller in size, their ventral floors being formed by the pleurapophysial elements. For the most part the comparatively rather small neural canal is subcylindrical in form, being most compressed vertically as we pass towards the distal cervicals, to become more cylindrical again in the ultimate free dorsal. After passing the fourth cervical, and from thence on to include the sixteenth, this tube is markedly of greater caliber behind than it is in front, in any single vertebra of this part of the spinal column.

This character can be particularly well seen in the eleventh cervical. Throughout, the parapophysial styles are very short. On the third vertebra they are far apart, but gradually approach each other and the median line to include the sixth cervical. Their character changes in the seventh, where they become sharp, short, and spiculiform. In the eighth, ninth and tenth they are represented by mere spinelets, close together mesiad and are to be found on the postero-ventral border of the carotid canal. From this on they gradually separate again, and entirely disappear from the ultimate cervical vertebræ.

The prezygapophysial facets are long, narrow and ellipsoidal in form on the third cervical, being considerably nearer each other at their posterior ends than they are in front. They face almost directly dorsad. As we pass to include the seventh cervical these facets gradually become more and more circular in outline, and incline to face towards the median plane. This they do quite abruptly in the eighth cervical—distinctly so in the ninth, look slightly backwards in the tenth, but again thereafter gradually right themselves so as to once more face the median plane. Here it will be seen we have the same arrangement noted for the Cormorant and the *Anhinga* though not nearly so well marked. The postzygapophyses are short and stumpy in the fourth vertebra, but very gradually lengthen to include the twelfth cervical, after which they once more shorten, to become short and thick-set again in the last cervicals, and the free dorsal, in which last—as distinct processes—they are practically aborted. Their facets for articulation with the corresponding ones on the prezygapophyses, are upon their ventral aspects, and of course have an exact counter-facing to them.

These vertebræ commence to lengthen after passing the third cervical, becoming quite longish and narrow in mid-series—they then very gradually assume the broad, massive, and short type found at the end of the cervical chain and in the free dorsal. Though these latter are large they agree with all the others of the column, from their extreme pneumaticity, in being very light in weight.

The three last dorsal vertebræ coössify, or rather in the adult Pelican are fused with those of the pelvic sacrum, and the leading vertebra of the latter is quite similar to one of the last dorsals, but in the next three the parapophysial processes are thrown up against and completely fused with the ventral surfaces of the ilia upon either side. These processes are spine-like and nearly aborted in the next following one, while in the next three they are absent entirely. This is well shown in the pelvis of *Pelecanus sharpei* (Pl. XXX., Fig. 49).

Then comes a true sacral vertebra, which has them long and well-developed, reaching out to points posterior to the acetabulæ where they fuse and broaden, and otherwise develop bone which greatly strengthens the pelvis in all this vicinity. The five remaining vertebræ of the "pelvic sacrum" also possess parapophysial processes, which with the diapophyses above them, most completely coössify with the internal borders of the ilia upon either hand. Of good capacity, the "pelvic basin" is of a short, oblong form, being one third narrower than it is long, and of nearly uniform depth throughout. Viewed laterally, we find the acetabulum to be large and circular; its internal periphery coequal with its external one. Above it is a fair-sized antitrochanter, facing forward and downward, and very slightly outward.

The obturator foramen merges completely with the obturator space, which latter is large and broadly spindle-form in outline. No prepubis is present, and the post-pubic style is curved and very slender until it comes in contact at a point on the postero-ventral angle of the ischium, after which it is turned slightly mesiad and somewhat though not at all greatly enlarged.

An extensive, subelliptical ischiadic foramen monopolizes much space on this lateral aspect of the pelvis. Behind it the surface of the bone is smooth, and finally we notice a broad, shallow notch on the posterior border, between ilium and ischium. Dorsad, the pelvis is broad, smooth and flat, with a thorough fusing of all the bones composing it. Parial foramina occur between the diapophyses of the uro-sacral vertebræ only in the post-acetabular region, where they are of good size.

The ultimate vertebra may be more or less individually outlined, and simulate in form the leading one of the caudal series. In the pre-acetabular region the ilia are moderately concaved, lie more or less in the horizontal plane, and fail to come quite in contact with each other over the "sacral crista," which latter is here quite low and indistinct, due to the thorough fusing of all the bones in this region. From the extreme outer point of one antitrochanter to the corresponding point on the same process on the other side measures, on a right line, about 7.5 cm., while the length of the "pelvic sacrum" is about 12 cm.

Thus, though steganopodous in character, this pelvis of *Pelecanus* differs materially in form and aspect from the pelvis of either a Cormorant or an *Anhinga*.

In the skeleton of the tail we find six free caudal vertebræ and a large pygostyle. All are highly pneumatic. The neural canal, of some considerable size, passes through the entire series and well into the pygostyle—an unusual occurrence in birds. All possess tuberous neural spines, but only the last three have hæmal ones, and these increase in size from the last caudal to include the fourth. They extend almost directly forwards. The transverse processes of the first five vertebræ are bent ventral-wise, more particularly in the second and third, while in the last one they are nearly aborted. The articular facets on the centra are concaved anteriorly, and nearly flat on the posterior aspects.

The large *pygostyle* is drawn out into a blunt point at its postero-superior angle. Its dorsal margin and the hinder half or more of its ventral margin are sharp—the remainder of the latter being thickened. The antero-inferior angle projects forwards, corresponding to the hæmal spine of the first vertebra absorbed to form this compounded bone.

Thus it will be seen that in this species of Pelican we have 41 vertebræ in its spinal column, namely: sixteen cervicals that are without free ribs; one cervical with well-developed ribs; one free dorsal; three dorsals fused with the pelvic sacrum; fourteen in the pelvic sacrum; and six caudals; the pygostyle not being included in this count.

The *sternum* and os furcula are intimately fused together at the carinal angle, forming there an extensive union. This is also the case in *Pelecanus sharpei* (Pl. XXVIII., Fig. 42). Apart from this fact, the sternum has much about it to remind us of that bone in *Phalacrocorax.* It is profoundly concave upon its dorsal aspect, and correspondingly convex upon the opposite surface. Either costal border, transversely very broad, is occupied nearly its entire length by the five hæmapophysial facets, with the long, shallow concavities that are between them. These latter are riddled with small pneumatic foramina, while only a few of these openings are found elsewhere in the sternum, and they are very minute. Two wide, shallow indentations mark the xiphoidal margin, and the lateral xiphoidal processes are short with rounded ends. They extend backwards and outwards. The deep keel projects somewhat forwards, but is merged upon the surface of the bone behind long before it reaches the posterior sternal margin.

Each "costal process" is low and of a subquadrilateral outline. On the anterior border of the bone there is a notable concavity, longitudinally disposed and of some considerable breadth. It extends from the upper termination of the anterior and rather sharp margin of the keel to lead into the general concavity of the dorsal aspect of the sternal body. It separates the long, narrow costal grooves in front, as well as the rather deep costal facets above them.

U-shaped in pattern, the lower loop of the *os furcula* is not particularly stout, while the chief feature of this bone is its enormously swelled and enlarged free upper extremities (Pl. XXVIII., Fig. 42).

These are entirely hollow, and each is provided with an elongated pneumatic foramen upon its postero-mesial aspect. Postero-laterally, either one presents for examination a subcircular facet for articulation with the head of the corresponding coracoid, internal to which a stumpy, tuberous projection extends backwards. But this fails by an extensive interval to meet the scapula, when the bones of the shoulder-girdle are articulated as in life. The mesial and outer aspects of these great clavicular heads are flat and smooth; anteriorly, their thickened borders are convex from above downwards, the posterior borders being concave. On top they each present a flat, triangular surface with the apex to the front.

From its extreme pneumaticity I find a *coracoid* in *Pelecanus fuscus* to be a very light bone, while it has an altitude of 9.7 cm., being large in its other proportions. The sternal end is considerably dilated, and to the other side is a very small up-turned epicoracoidal process. On the posterior side at the mesial angle there is a prominent jutting flange bearing an articular facet upon its entire under surface for articulation with the sternum. The inner two thirds of the inferior border is also for articulation with the same bone. The head is more or less massive, being obliquely compressed above. Well below this, anteriorly, is a non-elevated, circular facet for the os furcula. Above the large glenoid concavity, between it and the summit of the bone, is a deep valley passing downwards and forwards from the posterior aspect. Pneumatic foramina occur in it, as they do also on the mesial aspect of the shaft in an elongated group below the coracoidal head. The facet for the articulation with the scapula is a deep circumscribed concavity, and in front of it a conspicuous scapular process is developed, but it never reaches the os furcula in articulation when the bones are *in situ.* Below the open valley for the tendons, the shaft, is pierced by a foramen, a character often seen in birds of other groups.

A *scapula* is small in proportion for the size of the bird, thick, narrow and short. It is bent neither right nor left, but moderately curved, its convexity being along its dorsal aspect. It has a distinct ellipsoidal raised facet for articulation with the above-described pit in the coracoid, while the surface it offers for the glenoid cavity is small. Its most striking character is the very much elongated process at its antero-mesial angle. This acromial process does. not meet the clavicle in articulation. On the dorsal aspect of the blade, near its middle, is a distinct tubercle for muscular attachment, that is quite noticeable.

Of the Appendicular Skeleton.

(See Plate XXVII., Figs. 31–34, 38 and 39.)

In the *pectoral limb* the *humerus* is a very long, large bone showing the usual double sigmoidal curvature in its shaft, which for its middle third is subcylindrical in form. (See Pl. XXVII., Fig. 34.)

The radial crest is but moderately developed, while a peculiar tuberous enlargement is found on the ulnar border of the bone, just distad to the pneumatic cavity. It is stopped abruptly immediately before we come to the shaft, by a distinct though very narrow notch. The ulnar tuberosity is not very prominent, only partially overhanging the pneumatic fossa. Between it and the true humeral head is a distinct notch or valley. At the distal end of the shaft, the oblique and radial tubercles stand out with considerable prominence; the olecranon fossa is pretty well marked, otherwise we find only the usual ornithic characters here. The humerus has an extreme length of about 27 centimeters.

The ulna of the forearm is even much longer than this, being fully 32.5 centimeters in length, and from its great pneumaticity a very light bone. At its proximal extremity it has a very large pneumatic fossa just below the facet for articulation with the radius. The olecranon process is barely at all developed. Along the moderately curved shaft there are at least twenty-two distinct papillæ, nearly equidistant from each other, for the insertion of the quill-butts of the secondary feathers of the wing. On section, at its middle third, the shaft is triangular, and its distal end presents us with nothing peculiar. (The ulna of *P. sharpei* is shown in Pl. XXVII., Fig. 31.)

The *radius* is a long, slender bone and is also somewhat curved. Its distal end is transversely expanded, below, which expansion is the pneumatic fossa.

The *radiale* and *ulnare* of the *carpus* both plainly show the pneumatic fossa leading into them, as do all the bones of the manus. The *carpo-metacarpus* has an extreme length of about 12.4 centimeters. Along its continuity it is slightly carved anconad, while the very slender medius metacarpal stands well away from the main shaft, being somewhat longer than it is at the point of anchylosis distally. The pollex metacarpal is short and bulky. The carpo-metacarpus of *P. sharpei* exhibits the usual characters of this bone among the Pelicans (Pl. XXVII., Fig. 39).

The proximal phalanx of the index digit, with a length of 5 centimeters has a broad expansion posteriorly, and is peculiar in being perfectly flat and smooth upon its anconal side, while upon the palmar aspect it is divided into two deep concavities which are absolutely riddled with pneumatic foramina at their bases.

The terminal joint of this finger is long and trihedral in form, with its pneumatic foramen at the proximal end. Though a little longer than the pollex phalanx, the latter has very much the same shape, and is likewise pneumatic. The free terminal joint of the medius digit has a broadish, triangular expansion behind, and the holes for the admission of air pierce it upon both sides. This bone is 3.4 centimeters long, by 1.3 broad at its broadest part; while the distal joint of index has an extreme length of 4.6 centimeters.

In the *pelvic limb*, a *femur* although pneumatic to a certain degree, it is not so markedly so, as either the tibio-tarsus or the tarso-metatarsus. It will, in the dried skeleton, probably weigh more than the former, notwithstanding it is not as large, nor so long. Its stout shaft is but very little bowed in the antero-posterior direction, and the extremities are large and massive. The broad trochanter does not rise above the articular summit of the bone proximally, and the pit for the round ligament on the caput femoris is but little excavated. Distally, the condyles appear to be somewhat antero-posteriorly compressed, and transversely spread apart from each other. The external condyle is slightly the lower and larger of the two, and it is deeply cleft behind for the head of the fibula. Anteriorly, the rotular channel is shallow, nor is the popliteal fossa on the other side of the bone as deep in proportion as we find it in many other birds, both large and small, (Pl. XXVII., Fig. 32).

A *tibio-tarsus* instead of being bowed in the antero-posterior direction as it often is, it curves the other way so that the fibular border of the bone is convexed, and the opposite one, correspondingly, or even rather more, concaved. The extremities are large, but the several cnemial processes at the proximal one are but very moderately developed. Low and long, the fibular ridge extends down half the length of the shaft, and its articular margin or border is roughened. The tibio-tarsus of *P. sharpei* exhibits these characters very well, as they are seen in the *Pelecanidæ* generally (Pl. XXVII., Fig. 33).

At the distal end of the *tibio-tarsus*, the large condyles of the usual reniform outline, protrude prominently to the front, while behind they almost immediately merge into the general surface of the lower end of the shaft. The intercondylar interval is deeply excavated between them in front; at their lateral aspects the points for tendinal and ligamentous insertion are roughened and distinctly defined. A small bony bridge, such a frequent ornithic character, spans obliquely the anterior, longitudinal channel for the passage of tendons. In the deepest part of this recess, and directly under this little osseous bridge, a large pneumatic foramen enters the shaft of the bone. It is the principal aperture of this kind, by far, in the bone, and exists in the same place in the shaft of the fellow of the opposite side.

A *fibula* has its head and articular surface thereon moderately well developed, but the bone contracts rapidly as we proceed in the direction of its distal end, and after passing the articular surface for the tibia, it comes to be little more than a stout, bony thread, that by no means reaches the condyle of the tibio-tarsus, nor does it anchylose with its distal end.

Pelicans have, comparatively speaking, a very small *patella*, which is roughly wedge-shaped in form, with the flat base below, and the superior edge rounded, and not especially sharp.

The *tarso-metatarsus* is a stout, straight bone, with pronounced characteristics. The intercondyloid process upon its summit is rounded and conspicuous. Immediately below it, in front, terminates the usual longitudinal channel found on the anterior aspect of the shaft. It is deep here and opens into the shaft by a double pneumatic foramen. The inner one of these is large, and not only communicates with the interior of the shaft but passes also directly through it—appearing to the inner side of the base of the hypotarsus as a large foramen. Two or three much smaller foramina appear upon the opposite side of the hypotarsus, and they lead to similar passages through the shaft.

A prominent feature of this bone is its large hypotarsal process. This is composed of a thick, oblong piece or internal portion, which is capped upon its posterior aspect by an elliptical, vertical cap, having slightly protruding margins.

Two very much smaller such plates are developed external to this larger one, having each only about one half its altitude, and being not more than one fourth as thick. By their posterior surfaces more or less ossifying across, two vertical tubes are formed, an internal and external one, through which the tendons pass in life. As thus formed, this hypotarsus stands out rather abruptly and perpendicularly from the shaft, with hardly any inclination to merge with it at its lower part, as is the case in a good many birds. As to the shaft of this bone, it is convex posteriorly and strongly marked by the raised muscular lines; it is concaved slightly in front, the excavation being very deep proximally; shallow in the middle third; and deepening a little again as it passes into the usual foramen between and above the external and middle trochlear processes. These latter are large and normally disposed, the mid one being the lower of the three, while the internal and external project about equally backwards. The facet for the free first metatarsal is concave and of some considerable size. The *os metatarsale accessorium* is a little over two centimeters long, presenting the usual head and being slightly twisted upon itself distad. It agrees with the toe-joints in being non-pneumatic. These latter are nearly all straight, only some of the distal ones being slightly curved. For a bird as large as a Pelican they indicate rather a feeble foot, and this is further sustained when we come to see the weak terminal joints, which are transversely somewhat compressed, not very long, but withal distinctly, in fact rather strongly curved. These phalangeal joints are arranged upon the plan of 2, 3, 4, and 5 bones to the hallux, second, third and fourth toes respectively.

Pelecanus fuscus has a femur 8.5 cm. long; a tibio-tarsus of 12.5 cm.; a tarso-metatarsus of 7.8 cm. and a mid-anterior basal phalanx of pes of about 3.9 cm. in length.

When one comes to think of it then, a Pelican has rather a peculiarly balanced skeleton. Its lower jaw is considerably longer than its ulna, and the latter is in turn considerably longer than the humerus. This last-named bone is only a little more than half as long as the carpo-metacarpus of manus. The tibio-tarsus and the carpo-metacarpus are almost exactly of a length, the difference being only a millimeter in favor of the former.[19]

Further information in regard to the osteology of the *Pelecanidæ* will be given later on in the present memoir, as well as in the explanation of plates at its close. In Volume I. of the *Hand-List of Birds* by Dr. R. Bondler Sharpe (1899, pp. 238, 239), I find that he recognizes ten species of existing Pelicans, and seven fossil ones. They are found in nearly all parts of the world, including Australia, Tasmania and New Guinea. It is not likely that they differ very widely in their osteology, and it is probable that in its main features it is very well exemplified in *Pelecanus fuscus* as has just been set forth above.

Existing Pelicans have by ornithologists generally, all been restricted to the one genus *Pelecanus* of the family *Pelecanidæ*, where they undoubtedly belong.

On the Skeleton of Fregata.

(See Plate XXIX., Figs. 45–48; Pl. XXX., Figs. 50, 51.)

Of all the steganopodous birds perhaps no one of them exceed *Fregata aquila*, in point of interest, in so far as its osteology is concerned. In not a few particulars it has a very remarkable skeleton, while in others it would appear to indicate that the form or species is a more or less generalized one. For example, both superficially and otherwise, the *skull* of *Fregata* resembles, in not a few respects, the skull in some species of Albatrosses (*Diomedeidæ*). This not only applies to the lower jaw, where the similarity is very evident, but also to a number of characters in the cranium and face. The long, powerfully hooked superior mandibles are a good deal alike, as are the maxillo-palatines. *Fregata* has a vomer that approaches that bone in the Albatrosses; its palatines are not far off, and even still less so its pterygoids and quadrates. The lacrymals are upon the same plan of structure, and the entire

[19] There are some specimens of embryos and subadults both of *Pelecanus* and Cormorants in the U. S. National Museum collections, and at my request Mr. Lucas has examined some of these for me, and writes the following letter on the subject, for all of which it gives me pleasnre to thank him.

DEAR DR. SHUFELDT:

I have examined *Pelecanus* sp. about three or four days old and *Phalacrocorax carunculatus* for supramaxillary and found no trace in either. *Pelecanus* seems to mature more rapidly than *Phalacrocorax*. In the young Pelican the lacrymal is well developed and free, and there is no trace of the partial hinge joint at base of bill. There are traces of the three fused metatarsals and the calcaneum (?) is still free. In the young Cormorant the nostrils are still open, the lachrymal free. The occipital style is represented by ligament and were we all ignorant of its existence, it mght readily be overlooked. The hyoid is large. It would seem then that the supramaxillary does not appear until late in life and it may have no morphological meaning; simply it ossifies at the time of closing of nostrils. The occipital style of *P. carunculatus* is small in the adult. The specimen was about one third grown, and about ten days old probably.

Sincerely yours,

FREDERIC A. LUCAS.

cranium proper in the Man-o'-war-Bird might well answer for that of an Albatross but slightly removed from the typical stock. *Fregata*, however, lacks the deep supraorbital glandular fossæ so characteristic of the *Diomedeidæ*, and, from above downwards, the skull is somewhat more compressed than it is in, for example, such a species as the Short-tailed Albatross (*D. albatrus*) (Pl. XXIX., Fig. 46).

The superior mandible is broad at its base, and tapers gradually forwards, to be armed at the apex with a powerful and decurved hook which is exceedingly sharp at the point. This mandible is convex from side to side, moderately compressed, and concave longitudinally along the mid-line of the culmen, from the cranium to the base of the apical hook anteriorly. The narial apertures are small and situate each at the bottom of a fossa-like depression, while from them running directly forwards, one upon either side, is a distinct groove. It is rather deep, and very narrow, not being carried upon the hooked part of the bill at its distal termination.

No distinct cranio-facial hinge exists, but at the middle point in that region the proximal ends of the premaxillaries remain unobliterated throughout life (Pl. XXIX., Fig. 46).

Deeply concave towards each other, and with sharpened margins, the superior borders of the orbits are separated from each other by an interval of something more than 2 cm. Mesially, the intervening frontal surface shows a slight elevation, while in the parietal or post-frontal region there are two larger, convex and elongated elevations placed side by side with a median, not at all deep, depression passing between them. Within the cranial casket these elevations harbor the superior surfaces of the cerebral hemispheres, and the skull is thinner there than elsewhere (Pl. XXIX., Fig. 46).

The crotaphyte fossæ are well-defined, even better so than in an Albatross (*D. albatrus*), being very slightly depressed below the general surface, and, in the middle line posteriorly, do not meet by an interval of a centimeter (Pl. XXIX., Fig. 45).

Apart from this character, and the fact that the squamosal processes are more prominent and sharper in *Fregata*, the posterior aspect of its cranium agrees almost exactly, character for character, with what is presented to us on that view in the cranium of *D. albatrus*. In this I do not exclude the pterygoids and quadrates.

The large subvertical, subcylindrical foramen magnum is partially overarched by the well-defined occipital area, and the condyle, although of the same shape, is not quite as prominent as it is in an Albatross (Pl. XXIX., Fig. 48).

Seen upon side view, we are to note the deep valley of the temporal fossa, made so by the large outstanding post-frontal process anteriorly and the sharp, ridge-like squamosal projection referred to above (Pl. XXIX., Fig. 45).

The *lacrymal* is a free bone articulating by its upper portion with the free border formed by the frontal and nasal bones, while its descending limb is bulbous at its lower extremity, and fails to reach quite the maxillary below it. The pars plana is nearly aborted, there being merely a small bridge of bone left, that arches over the anterior end of the nasal nerve as it enters the rhinal chamber. This nerve passes in an open groove, but is again shielded by an osseous span, just as it enters the orbit. The "foramen rotundum" is large and is distinct from a still more extensive vacuity which is seen above it on the anterior wall of the cranial casket. No foramina exist in the interorbital septum proper. Occasionally a small distinct nerve foramen is seen to the outer side of the opening for the exit of the optic nerve. The anterior border of the mesethmoid is both concaved and sharpened (Pl. XXIX., Fig. 45).

The zygomatic bar is quite straight, being transversely compressed at its quadratojugal end, to become twisted upon itself in the jugal part, and so vertically flattened for the remainder of its extent or in the maxillary moiety. The extreme anterior end fuses in between the premaxillary and nasal. At the hinder extremity we find the usual little peg articulating in the pitlet on the outstanding process of the quadrate (Pl. XXIX., Figs. 45 and 48).

As has already been remarked above, one of these last-named bones bears a very close resemblance to the quadrate in an albatross. The orbital process of the *os quadratum* in *Fregata* is antero-posteriorly compressed just as it is in *Diomedea*, and its free extremity is expanded and finished off in the same manner.

We notice a slight difference, however, in the form of the internal articular facet of the mandibular end of the bone. It is more compressed from before, backwards in *Fregata*, and the articular surface presents but one common convexity, whereas in *Diomedea* this facet is impressed by a deep, oblique valley, the axis of which is parallel to the pterygoid of the same side.

As in the Albatross, a *pterygoid* bone is a straight, stout element, with somewhat enlarged anterior end, and a markedly expanded posterior one; in the last character being much more enlarged than it is in *Diomedea*. Both birds have their pterygoids pneumatic, and when articulated *in situ*, they touch each other in the middle line, beneath the sphenoidal rostrum.

In *Fregata* the basitemporal region is small and of a triangular outline; the eustachian passages are very open canals, and their anterior beginnings are separated by quite an interval — the base of the sphenoid standing distinctly between them (Pl. XXIX., Fig. 48).

Although morphologically very much alike, the *palatines* in *Fregata* fuse together where they come in contact with each other posteriorly, which is not the case in any Albatross ever examined by me. The ascending and descending laminæ are not so powerfully developed as they are in the Albatrosses, but in *Fregata* we still find the broad, horizontally flattened anterior moieties of the palatines, with the mesial, elongated and narrow interval separating them. At the fore part of this we likewise see the *maxillo-palatines,* similarly separated, with their *external* borders and surfaces accurately fused with the contiguous bones. Between them, we discover the sharp apex of the extremely slender, and long, and free, and curved *vomer* of the Man-o'-war Bird, so very suggestive of being an extreme modification of that element as we found it to exist in *Diomedea.* (See Figs. 16 and 17, in my memoir on the Osteology of the Tubinares and Steganopodes, P. U. S. N. M., 1888, p. 279, for the vomer in an Albatross.)

The postero-external angle of a palatine in *Fregata* is inclined to be somewhat produced, whereas in the *Diomedeidæ* as a rule that angle is rounded off (Pl. XXIX., Fig. 48).

Upon examining the *mandible* in *Fregata* it also presents a number of characters it has in common with that bone in *Diomedea.* In form it is a long V-shaped structure, with truncated postero-articular ends. The rami are strong and thick; the ramal vacuities are closed in; the rather meager symphysis is decurved and sharply pointed at the apex. Along the superior margin of either dentary portion, runs a distinct groove; these borders being cultrate in the Albatross, and the aforesaid groove being conducted down upon the mesial aspect of the dentary element, where it is far less pronounced, and its nature not so marked. The mesial aspect of either dentary part of the jaw in *Fregata* is also *deeply* grooved for nearly its entire length; this last groove is but faintly developed in *Diomedea,* and that only at the anterior third of the bone (Pl. XXIX., Fig. 47).

Fregata has a more pneumatic mandible than *Diomedea,* and the foramen at either articular end is, in the former genus on top of the mesial process, while in the latter it is situated at the *base* of the obliquely-disposed, deep, central concavity, or, in other words, that concavity which is intended to accommodate the inner large articular facette on the quadrate. It is single and circular in either case.

Fregata has a very simple skeleton as to its *hyoidean apparatus,* for the fore part is considerably aborted, while behind all the elements do not ossify. The small glossohyal is performed entirely in elementary cartilage, and only the diminutive ceratohyals, which are distinct from each other, ossify. The short, rather bulky, first basibranchial ossifies, but there is no sign of a second one. Of the thyrohyal elements, the ceratobranchials are long, slightly curved, and completely ossified; the epibranchials are in cartilage only. In my specimen the *sclerotals* of the eye, and the bony elements of the internal ear, are missing.

Of the Remainder of the Axial Skeleton.

Upon examining the vertebral chain of *Fregata aquila* we find in it thirteen vertebræ in the cervical region, that do not support free ribs; the fourteenth vertebra has a long, slender pair that are without unciform processes, the next five, all freely movable upon each other, connect with the sternum by means of their costal ribs or hæmapophyses; then, finally, there are two pairs of pelvic ribs, but it is only the costal ribs of the leading or anterior pair, that connect with the sternum. In the specimen before us, we may call them, from the fifteenth to the nineteenth vertebra inclusive, true dorsals, while counting, as best we may, the number of vertebræ fused together in the pelvic sacrum, there appear to be fourteen in all. Next follow six free caudals and a large pygostyle.

Since the first part of this memoir was written I have had placed before me, a skeleton in the rough of the Great Wandering Albatross (*D. exulans*), and upon comparing the arrangement and number of its vertebræ with what has just been given for *Fregata*, we find it to be dissimilar in many particulars. This leads me to think that with respect to the spinal column, the ribs, and the vertebræ, no *typical* Albatross will be found to agree with the Man-o'-War Bird.

Pneumaticity is a prominent character of the trunk skeleton of *Fregata*, and it would seem that all the bones enjoyed that state. The *atlas* has a broad neural arch, and its cup instead of being perforated, is extensively notched above. On the *axis* the "odontoid process" is short and stumpy; and its hæmal spine is also an insignificant affair. On the dorsal aspect of this vertebra, the neural spine is broad and tuberous, while the postzygapophysial processes are much swollen also. These latter, in the third vertebra, are joined upon either side with the prezygapophyses by means of a somewhat delicate interzygapophysial bar. A large hæmal spine is present here, and a low neural one. The same character is to be found in the fourth vertebra, and both third and fourth possess short backward-projecting parapophysial spines.

In the fourth or fifth cervical a distinct neural process exists; it is absent again to include the ninth vertebra; it is but faintly developed in the tenth, and from thence backward it gradually increases in proportion and changes in form, until we have the low, quadrate plate of the dorsal series. Throughout the latter, hæmal spines are absent, and from the fifth to the tenth vertebra inclusive, the carotid canal exists, unclosed as it is by the rather feebly produced parapophyses. From the third vertebra to the thirteenth inclusive, lateral vertebral canals are to be found, and in the fourteenth vertebra the pleurapophysial elements free themselves as a pair of ribs. It is only in the last three dorsals that metapophysial spines, of no great length, extend backward from the postero-external angles of the transverse processes, and in these three vertebræ, upon their dorsal aspects, a pneumatic pit is found, on either side, posterior to the prezygayophyses. The mode of articulation among the centra is of the common ornithic character, and one of the chief features distinguishing these vertebræ is the lack of prominence, or even entire absence, of projecting processes, so conspicuous in many other birds. A good example of this is seen in the eighth, ninth, tenth and eleventh vertebræ, where the tendency of the short parapophysial processes is to merge with the centra by means of osseous bridges connecting the two; and another is the marked absence of hæmal spines.

As near as I can judge from my specimen, the arrangement of the ribs of *Fregata* is as follows: On the fourteenth vertebra there is a rudimentary pair, while on the fifteenth there is a long, slender pair of free ribs, that are without epipleural processes. These are well-developed on the succeeding pair belonging to the sixteenth vertebra; and this pair of ribs are the first of the series to connect with the sternum, by means of rather short hæmapophyses, the ribs of the dorsal series, seventeenth to nineteenth vertebræ inclusive, are long, very narrow, highly pneumatic, and are characterized by the unusual length of their epiplural spines. They all have costal pairs of ribs, gradually increasing in length, and connecting with the sternum.

Two pairs of pelvic ribs are seen, both lacking epipleural appendages, and the ultimate pair anchylosed with the vertebra to which they belong, and with the ventral surfaces of the ilia. The last pair of costal ribs fail to reach the sternum.

The *pelvis* is broad and flattened. Anteriorly one entire vertebra projects beyond the ilia, but it is coössified in its position with the "sacrum."

Viewed from above, we are to note that the ilia are widely separated from the sacral crista, which latter are very large, rounded and depressed. Slight concavity characterizes the preacetabular iliac areas, and the anterior emarginated borders of these bones are very obliquely truncated from their antero-mesial angles backwards. The interdiapophysial vacuities in the uro-sacral region are of considerable size, and the most part they have a parial arrangement and are very large in front.

The postacetabular areas are about equal in extent to the anterior ones, and are convexed as much as the latter are concaved. Bony fusion between the ilia and the vertebræ is, in all this region, very perfect, extending clear to the sacral extremity, and no part of the latter projects posteriorly beyond the iliac bones.

Upon lateral view of this pelvis we note that the ischium (upon either side) is much drawn out behind, and there pointed. It may be said that hardly any ilio-ischiadic notch exists, the usual site for it being very shallowly rounded off. For their anterior moieties the pubic styles are very slender, but their elongated posterior ends are more clubbed and thickened, where they come simply in contact with either ischium above them. On the lateral aspect the antitrochanter is seen to be not very prominent; and the cotyloid ring and ischiadic foramen have their usual ornithic characters. Posteriorly, the obturator foramen opens most completely into the space of the same name; thus, in reality, merging the two vacuities into one. In the capacious pelvic basin on the ventral aspect we find the last six parapophysial struts of the vertebræ, when present, very distinct and slender, being thrown up as braces in the usual manner. This feature also obtains with all the vertebræ at the fore part of the sacrum, and indeed, there are only two in the series that entirely lack this development of the parapophysial processes, they being the twenty-sixth and twenty-seventh of the vertebral chain as a whole.

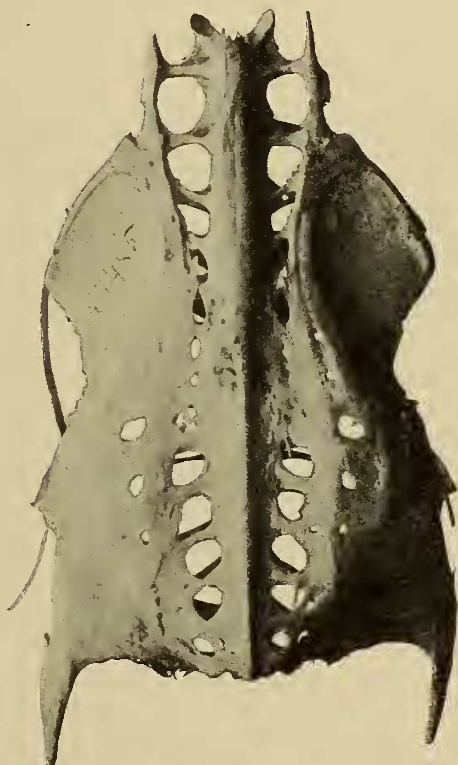


FIG. 37. Dorsal aspect of the pelvis of *Fregata aquila*, very slightly reduced. From a photograph by the author of the specimen in the collection of the U. S. National Museum (No. 18485).

This pelvis is very light and highly pneumatic; air-holes always occurring in a small group immediately in front of either cotyloid ring, as well as in many other places.

Moreover, in many respects the pelvis in *Fregata* is a very differently characterized bone from what we find in an Albatross.

In the skeleton before me, I find *six* large, free *caudal vertebræ*, besides a big parallelogrammatic *pygostyle*. The vertebræ have very long, depressed, narrow diapophyses, the anterior and posterior borders of which are rounded off. Stumpy, bifid, centrally perforated hæmal spines are found only in the last two or three, while in all these vertebræ, so light from the high state of pneumaticity they enjoy, the neural spines are elevated and pointed. The neural canal, nowhere very large, seems to extend even into the pygostyle. This latter bone has a rounded superior border, while below and behind it is thickened and broadened. At its lower part it is usually transversely perforated by an oval foramen of some size. Above its anterior concave articular facet the margin is sharp, the corresponding posterior one being rounded. In the more expanded part below this latter margin, we find the numerous pneumatic perforations that lead into its interior parts. The large pygostyle of an Albatross is triangular in outline, and the caudal vertebræ of one of these birds bear but slight resemblance to those bones in *Fregata*.

A number of anatomists in various places have already invited attention to the striking peculiarities of the *sternum* and *shoulder girdle* of the species we here have under consideration (Pl. XXX., Figs. 50 and 51).

In the specimen at hand, I find that the symphysis of the furcula is extensively coössified with the fore part of the carina of the sternum, while its upper clavicular extremities are in a like manner very completely fused with the mesial aspects of the summits of the coracoids, upon either side. The sternal ends of these latter bones form free articulations with the sternum, and the scapulæ are also freely articulated each with the corresponding coracoid. This description, it will be seen, differs from what Newton found in a specimen of *Fregata*, and he says, "In one very remarkable way the osteology of *Fregata* differs from that of all other birds known. The furcula coalesces firmly at its symphysis with the carina of the sternum, and also with the coracoids at the upper extremity of each of its rami, the anterior end of each coracoid coalescing also with the proximal end of the scapula. Thus the only articulation in the whole sternal apparatus are where the coracoids meet the sternum, and the consequence is a bony framework which would be perfectly rigid did not the flexibility of the rami of the furcula permit a limited amount of motion."[20]

My skeleton is from an adult bird, as no doubt the one examined by Professor Newton was, and this makes the circumstance all the more remarkable.

In Albatrosses the symphysis of the furcula also fuses with the sternum, while the sternum, coracoid, and scapulæ of some of those birds bear other slight resemblances to the corresponding bones in the skeleton of the Man-o'-war Bird.

Fregata has a very short sternum, being about as long as it is broad. The body above is profoundly concaved, where it shows numerous pneumatic foramina especially down the median portion. Either costal process is triangular, pointed and lofty, and the costal borders short. They about equal in length, however, on either side, the sharp-edged lateral margin.

The rather short xiphoidal processes are situated, one at either posterior-external angle of the body of the bone, and they are rounded off behind. For the rest, the xiphoidal border that joins them is nearly an unbroken transverse line, exhibiting

[20] Alfred Newton, "Dictionary of Birds," Art. Frigate-Bird, Part I., pp. 293, 294, London, 1893.

neither notches or indentations. Ventrally, the carina extends the entire length of the bone, its lower margin being very convex and thickened ; the lateral edges of the latter extending beyond the sides. The anterior carinal boundary is sharp and short surmounted above by a rudimentary manubrium. Either costal groove is deep and wide, and the coracoids, when articulated *in situ*, meet in the median line above, where they separate the anterior sternal border and the small trihedral manubrial process.

The os furcula is of the U-shaped pattern, and is coössified, as has been said, with the sternum and coracoid. Its rami are narrow and compressed, with its hypocleidial portion below very broad, triangular in outline, slightly concaved in front, and withal antero-posteriorly compressed. Above, the clavicular ends are transversely very thin. Either one shows two places of bony fusion ; one at the tip, and a still more extensive one in front of the head of the coracoid. Mesiad, between these, there exists an oval foramen. The clavicular extremities are separated from each other by a distance of 6 centimeters. By far the largest bone of the pectoral girdle is the *coracoid*. Either one of them has a height of 8.5 cm. with a large shaft and broad sternal end. A minute epicoracoidal process is present, and the clavicular process, although pretty well developed and curving forwards, does not reach the end of the clavicle by quite an interval. The glenoid cavity faces more than usual to the rear, much as it does in an Albatross. Measuring on its chord, a scapula has a length of about 8 centimeters. Its inner border is convex, and its outer more decidedly concave. For its middle third, the bone is narrow and thickened, the distal extremity being slightly dilated, compressed from above downwards, and brought to a rounded point posteriorly. Its coracoidal extremity is also much compressed in the vertical direction, very wide from side to side, with its inner angle drawn out into a well-developed process, and with a small glenoidal facet occupying the other one.

The Pectoral Limb.—The bones making up the skeleton of the upper extremity are all completely pneumatic, and, as compared with those of the pelvic limb, are chiefly remarkable for their enormous comparative lengths. This is well shown in the following table :

Length of	Humerus	21.0 cm.
"	Femur	5.7 "
"	Ulna	27.5 "
"	Tibio-tarsus	7.5 "
"	Radius	26.6 "
"	Fibula	6.5 "
"	Carpo-metacarpus	13.0 "
"	Tarso-metatarsus	2.4 "
"	Index digit	12.5 "
"	Mid-anterior toe	7.6 "

The *humerus* presents the usual double sigmoidal curve seen in the humeri of almost all birds. Its shaft is smooth and subcylindrical in form, being somewhat compressed from side to side. The pneumatic fossa is inclined to be shallow and the foramina in it very small; but there are pneumatic openings in other parts of the bone, notably at the distal extremity, where large ones occur upon either aspect. The radial crest or the crista superior is very prominent, being of a triangular outline, with a thickened border distad. The ulnar tuberosity or the crista inferior is also conspicuously developed, with the tuberculum internum much produced. The caput humeri is elongated and spindleform; it is separated from a flat tuberous area on the ulnar side of the palmar aspect by a deep transverse sulcus, the sulcus transversus. At the distal end of the bone the muscular grooves are very deep on its anconal aspect, the ulnar side apparently much raised in consequence. A deep fossa exists both palmad and anconad to the trochleæ. A low ectepicondylar eminence is present, with deep, circumscribed muscular pits near it on the radial border. No very special resemblance exists between this bone in *Fregata* and the humerus as it is found in any of the typical Albatrosses. The same would seem to apply to the remainder of the skeleton of this limb.

In the *ulna* we find the shaft somewhat more cylindrical than it is in the humerus, and presenting but a very slight degree of curvature. It has two distinct rows of papillæ for the quill-butts of the secondary feathers, the more prominent row being represented by eighteen of them. The concavities for the trochleæ of the humerus are deep with raised edges, but the olecranon process is low and tuberous. Its distal ends present the usual ornithic characters, with muscle-grooves very distinctly marked.

The *radius* viewed upon its superior aspect presents for its length an elongated sigmoidal curve. This curve for its distal two thirds nearly agrees with the curvature of the shaft of the ulna, when the bones are articulated *in situ;* while for the proximal third it is reversed, and here occurs a long, narrow, spindle-shaped "interosseous space." The radial shaft is more or less cylindrical, smooth, and but faintly marked by muscular lines or ridges. The distal end of the bone is considerably expanded in the transverse direction, and here pneumatic foramina are to be seen. Its proximal head is only moderately developed, and it is the middle third of the continuity of the shaft that possesses the greatest caliber. This latter very gradually diminishes as we approach the extremities.

Fregata when adult has in its wrist the two usual carpal segments, which, from the high state of pneumaticity they enjoy, are extremely light. Although they have the usual form seen in birds, they are here powerfully marked by the various muscular-grooves and articular facets that characterize them.

The *carpometacarpus* also presents us with the common ornithic features; though from its great pneumaticity, it is one of the lightest bones of its size we have ever met with in the class. The pollex metacarpal forms a large triangular projection at its usual site, while the shafts of the index and medius are nearly straight and parallel with each other; the former being fully six times the bulk of the latter. Distally, neither one projects beyond the other, as is sometimes the case in birds of other groups.

The expanded portion of the proximal phalanx of the index digit is both perforated and riddled with pneumatic foramina of various sizes and shapes, and upon both sides. This part sends down a conspicuous rounded process beyond the proper shaft of the bone, while from the antero-distal aspect of the shaft itself, a similar process projects forward. At the proximal extremity are two other apophyses standing out from the bone, one being upon its anconal and the other upon its palmar side, while the plane of the articular surface of the summit extends, to some extent, over and upon each. The distal or terminal phalanx of this finger is of great length; trihedral in form; and much scooped out posteriorly. Pneumatic foramina enter it at various points, one, somewhat elongated, even occurring at its apex. The pollex digit is not more than two thirds the length of the one just described, and its posterior aspect, instead of being scooped out, is very sharp and prominent; and this border in the still smaller phalanx of the medius digit, has upon it a low tuberous apophysis for muscular attachment. None of these terminal joints of the fingers appears to bear claws at their extremities.

The Pelvic Limb.—Feebleness of a very marked character stamps every bone of the lower extremity in *Fregata*. The skeleton here is, moreover, largely non-pneumatic. It is, apparently, only the femur and proximal moiety of the tibio-tarsus that enjoys that state at all. The former bone is quite as pneumatic as the humerus of the arm, while the portion of the tibio-tarsus mentioned appears to be only moderately so.

The *femur* is short and bulky, with its head very distinctly sessile, and its upper part markedly scooped out for the insertion of the round ligament. The trochanterian ridge does not rise above the articular summit of the shaft, and it is broad and flat in the antero-posterior direction externally. Below these parts extends the short, straight, cylindrical shaft, more or less strongly marked by the usual muscular lines. The condylar portion or distal end is weakly developed, though all the characters common to the femora of most birds are present. A fibular notch is well defined, and the external condyle is placed lower down on the shaft. Both the popliteal fossa and rotular channel are very shallow; the latter, it may be said, hardly exists at all. Pneumatic foramina are always found at the base of the former, immediately above the internal condyle.

Lack of salient characters distinguishes the *tibio-tarsus* even more profoundly than the femur. Its cnemial crest and processes are almost completely reduced, the former barely rising above the nearly level articular summit of the bone. Comparatively short and quite straight, its shaft is of decidedly slender bulk, being subcylindrical in form. The fibular ridge is confined completely within the limits of its upper third, being but a little more than a centimeter in length. Its articulation with that bone is very free. At the distal end we find a pretty well developed pair of condyles, but the osseous bridgelet in front is low down and weak, indicating that the tendons too, which it is intended to hold in place, must also be but feebly developed.

The *fibula* is nearly complete, its lower end, of hair-like dimensions, is fused with the side of the shaft of the tibio-tarsus immediately above the external condyle of the latter bone. Above its proximal articulation, the fibula is of larger size, standing in strong contrast with the very slender straight part below that point.

Fregata has a flake-like *patella* of some size, being quadrilateral in outline, and marked obliquely across its anterior surface by a groove for the ambiens muscle. As with the vast majority of birds, it is non-pneumatic in character.

The tarso-metatarsus is wonderfully short and thick-set. This bone is so much abbreviated in the direction of its longitudinal axis that it hardly appears to possess any shaft at all. Antero-posteriorly it is flattened, while transversely it is relatively broad. On its anterior surface well-marked grooves plainly indicate the three metatarsal elements of which it is composed, while posteriorly the short shaft is quite flat and smooth. Its hypotarsus is bulky and circumscribed, — not extending down the bone, — while a single central canal pierces it for the passage of the tendons. This is of some size. Distally, the trochlear processes are comparatively large and spreading. They all lie in nearly the same transverse plane, the inner one being the lowest in position; the outer, the highest; and the middle one occupying an intermediate place. The foramen for the passage of the anterior tibial artery is peculiar, inasmuch as its lower exit is in the sulcus between the outer and middle trochlear projections instead of on the back of the shaft above that point, where it is usually to be found. The accessory or first metatarsal is as large in proportion as in those birds where the skeleton of this limb is harmoniously developed in point of size with the rest of the osseous system. All the phalangeal joints of the pes are well developed, being arranged upon the plan of 2, 3, 4, 5, for the first to fourth toe respectively, and were not this part of the skeleton of the foot ridiculously small for the size of the bird to which it belongs, it might, with truth, be said to be very well developed.

The ungual joints are powerfully curved, and considerable curvature characterizes the majority of the others, especially those of the first, second, and third toes. Although a digression from the consideration of the osteology of *Fregata*, it is interesting to note that the greatly developed podotheca of the ungual joint of the middle toe is beautifully pectinated, — a fact, in the present instance at least, that distinctly militates against the view, still entertained by a few ornithologists, that the function of the toes of birds so armed is the possession of an instrument wherewith they may rid themselves and their plumage of vermin.

Relationships of the Steganopodes.

If we base our judgment on the osteology of the birds that have been examined in the present memoir, it would seem that we are justified in regarding the Suborder Steganopodes as being composed of three superfamilies. These may be designated as, first, the *Pelecanoidea;* second, the *Phaëthontoidea;* and third, and lastly, the *Fregatoidea.*

Arranging these, and arraying the existing families of them, with their genera, a taxonomic scheme on such a basis would stand thus:

Superfamilies.	Families.	Genera.
Pelecanoidea	Pelecanidæ.	Pelecanus.
	Phalacrocoracidæ	Phalacrocorax. Nannopterum.
	Anhingidæ.	Anhinga.
	Sulidæ.	Sula.
Phaëthontoidea.	Phaëthontidæ.	Phaëthon.
Fregatoidea.	Fregatidæ.	Fregata.

The genera and families of fossil forms are not taken into consideration in this scheme.

Ornithotomists are agreed that the *Steganopodes*, constitute a well-defined group, but beyond this the majority are reticent as to the question of the affinities existing among the families and genera making up this group, and the relations of it as a whole to other avian groups in the system.

If from among the *Phalacrocoracidæ* we select the genus *Phalacrocorax,* there is no doubt, in so far as its osteology indicates, that it is closely related to the genus *Anhinga.* This, as has been shown above, is evident from a direct comparison of the corresponding bones of the skeleton of any species of Cormorant with those of the skeleton of *Anhinga.*

On the other hand, and by similar methods, there is no disguising the kinship existing between *Phalacrocorax* and *Sula,* although the gap between these genera is somewhat greater than the one standing between the Cormorants and the Anhingas.

Pelicans of the genus *Pelicanus* are aberrant forms which, as osteologically indicated, have varying relations with all three genera thus far mentioned. They are however, apparently more nearly related to *Sulidæ* than they are to the Cormorants.

From the *Pelecanoidea* the passage to the *Phaëthontoidea* is not far to seek, for upon comparing the corresponding bones in the skeleton of such a Gannet as *Sula brewsteri* with those of *Phaëthon flavirostris* we are at once confronted with so many points of similarity as to leave no doubt in our minds that it is between the genera and families represented by such species as these that the linking of the two groups takes place.

This is important, for in another direction we are led, on the one hand, through *Phaëthon* to the suborder Longipennes, and on the other to the suborder Tubinares; *Phaëthon flavirostris* having some osteological characters that strongly suggest larine affinities, and still more that bring to mind the skeleton of a *Puffinus.*

Their distinct maxillo-palatines, their perforate nostrils, their hardly coalesced palatines, their four-notcheds ternum, and their ilia widely separated from the "sacral crista," taken in connection with numerous other important skeletal characters, fully entitle the Tropic Birds to rank as a superfamily — the Phaëthontoidea as given above.

There can be no doubt about *Fregata,* for the skeletal characters seen in its skull, its sternum and shoulder-girdle, its pelvis and limbs, and in its trunk skeleton, as we have in detail described them above, stamp it at once, not only as being a form having many skeletal characters completely at variance with those found in average steganopodous birds, as Cormorants and Gannets, but as a type likewise for which a superfamily must be created, in order to show that these striking departures are fully appreciated by the student of its osteology. As indicated in our scheme above, this superfamily may be designated as the Fregatoidea.

The pelvis in *Fregata* is decidedly more like the pelvis in *Phaëthon* than in other Steganopodes. In its pelvic limb-bones, which are extraordinarily short and otherwise weak, as compared with the very lengthy pectoral ones, and the size of the rest of the bird, it stands quite unique in the suborder to which it belongs. More remarkable than all, however, are the many characters in its skull, which powerfully recall the Albatrosses among the Tubinares. These are so evident that one is almost led to believe, if it be not actually the case, that the strong-hooked beak in the skull of *Fregata* is a diomedean character rather than a pelicanine one. Apart from the free ends of the furcula coalescing with the coracoids, there are characters in the sternum and shoulder-girdle of *Fregata* which also recall the forms of the corresponding bones in the Albatrosses, but beyond this there appears to be nothing else in the skeleton of the Man-o'-War Bird at all reminding us of those birds.

As this relationship exists between *Fregata* and *Diomedea*, remote as it may be, it nevertheless, taken in connection with what has been pointed out above in regard to *Phaëthon* and *Puffinus*, ought to lead us to believe that the STEGANOPODES are more closely affined with the TUBINARES than they are with the LONGIPENNES.

There are those who claim to see a kinship existing between the *Accipitres* and the FREGATOIDEA, but there are surely no indications of it in so far as the osteology of any of the representatives of the two suborders in question are concerned.

ADDENDA.

Since writing the above account of the osteology of the *Steganopodes*, I have personally reëxamined some of the material in the United States National Museum, and, thanks to the marked kindness of Mr. F. A. Lucas, the able Curator of the Department of Osteology of that institution, I have been permitted fully to examine and compare the entire collection there, constituting as it does the finest assortment of material illustrating the osteology of the *Steganopodes* in existence. A number of the specimens drawn from this material are now figured for the first time in the plates to the present memoir.

To what I have already set forth in the body of the paper, there is nothing I find in particular to add to the osteology of the *Phaëthontidæ* or the *Sulidæ*. Among the *Plotidæ* (the *Anhingidæ* of the A. O. U. "Check-List") I examined a skeleton of *Plotus levaillanti*, and it presents all the usual characteristics of the skeleton in that family of birds. A dorsal view of its pelvis is given in Plate I., Fig. 1, which will assist in illustrating what I have said in the body of the memoir in regard to the skeleton of *P. anhinga*. I have never had the opportunity to examine the skeletons of the two other known species of this family. (Sharpe's "Hand-List of Birds," p. 236.)

The collection of Cormorant skeletons (*Phalacrocoracidæ*) in the U. S. National Museum is, as I have said above, the finest in the world at the present writing, nearly every known species being represented. It is Mr. Lucas' intention, sometime in the future, I understand, to monograph this group, and it will be a very valuable contribution to the subject. Their skulls present some very interesting variations, and the majority of these are well shown in the figures of the Plates illustrating this memoir (Plate IV., Figs. 13–21 and Plate VI., Figs. 25, 27 and 29). They not only vary in size according to the species, but perhaps the most interesting variation they offer is the marked vertical compression of the skull they exhibit, associated, as it is, with a decided elongation and narrowness of that part of the skeleton. This is well seen in such a species as *Phalacrocorax pelagicus robustus*, where this character about reaches its maximum. At the other extreme, we find the skull of some Cormorants to be moderately shortened, with a broad, dome-like cranium, which admits of an unusually capacious brain cavity. A species having this character markedly exemplified is *Phalacrocorax albiventris*, and its skull is shown in Plate IV., Figs. 14 and 21, and in Plate VI., Fig. 29. A good medium type standing between these two extremes is seen in *Phalacrocorax dilophus*, while all the other species of Cormorants tend either toward *P. p. robustus*, or toward *P. albiventris* in the matter of this flatness and elongate-narrowness of their skulls, or in the shorter, broader and more capacious cranium of the last-named species. The shading either way is often so gradual that everything else being equal, it hardly seems to offer justifiable grounds for generic divisions. Associated with these forms of the skull in the Cormorants, we are to note the variation in the form of the pterygoid bones at the inferior aspects of the same. Some *Phalacrocoracidæ* possess long and comparatively slender pterygoids, while other species have them much shorter and stouter. *Phalacrocorax p. robustus* is an excellent example of the first of these (Plate VI., Fig. 28), while *P. albiventris* well exhibits the last-named condition, while in *P. dilophus* again, they are moderately elongated and fairly stout, thus once more, affording an example of the medium type in this particular. In some Cormorants the mesethmoid bone is not perforated by a large median vacuity, as is seen to be the case in others. It is thus perforated in such species as *P. p. robustus* and *P. albiventris*, while it is perfectly solid in such forms as *P. dilophus* and *P. melanoleucus*. There are also interesting differences to be noted in the comparative size and form of the foramen magnum, the morphology of the cranio-facial hinge, and other minor points, the majority, of which, if of any importance, are noticed in the body of the present memoir.

The pelvis in the various species of the Cormorants also exhibits a difference in form. In *P. pelagicus*, for example, it is comparatively short, narrow, and with the ilio-ischiatic notch not very deep, while in *Graculus Carbo*, it is much elongated, narrow, and the aforesaid notch very deep. Other species of the *Phalacrocoracidæ* tend one way or the other in this particular. The short-bodied Cormorants have the sternum more or less broad and short, while in the long-bodied species this bone is likewise more elongated and narrower.

As I have shown in this memoir all Cormorants possess a big *patella*. Mr. Lucas in studying this bone has observed that this sesamoid in some of the species is perforated for the passage of the ambiens muscle, while in others it is not so, but this perforation is not associated with other characters in such a manner that the condition can be regarded as having any taxonomic value. Mr. Lucas at my request kindly examined this point for me in quite a number of species of Cormorants, and found that the patella is thus perforated for the ambiens in *Graculus Carbo*, *Phalacrocorax dilophus*, *P. vigua*, *P. harrisi*, *P. Magellanicus*, *P. albiventris*, (where it is small) and in *P. pelagicus*, while the patella is imperforate in *Phalacrocorax melanoleucus*, *P. punctatus*, *P. penicillatus* and *P. urile*.

Osteologically, the *Pelecanidæ* constitute quite a homogeneous group of birds, and certainly a thoroughly circumscribed family of the *Steganopodes*. I have examined the skeleton in several species, but more particularly in the case of *Pelecanus sharpei*, *P. fuscus*, *P. onocrotalus*, and *P. erythrorhynchus*. In some species the mandibles are broad and comparatively shorter than they are in others, and, when so, they are compressed from above downwards. This is the case in *P. sharpei* (Plate VII., Figs. 36, 37), and in this species we note in its skull that upon the lateral aspect of the superior mandible, just where it is joined to the maxillary bone, the compact tissue is continuous downwards to the anterior end of the corresponding palatine, completely overlying and concealing, on side view, the spongy tissue of bone in the rhinal chamber, (Fig. 37). Whereas in such a species as *P. fuscus* there is a large triangular interval left open here, so that upon the same view we are enabled to see almost the entire mass of the osseous spongy tissue of the aforesaid space, (see Fig. 40 of my memoir, "Observations upon the Osteology of the Order Tubinares and Steganopodes," Proc. U. S. Nat. Mus., 1888, p. 312). In the drawing referred to the upper and lower edges of the united palatines have been shaved off, but I was quite a juvenile osteologist when I prepared that specimen; indeed it was my first osteological preparation (1864). The correct form and outline of the lower united edge of the palatine bones is shown in the case of *P. sharpei* in Plate VII., Fig. 37, of the present memoir. In Figs. 35 and 40 of that plate I would say that the horny podotheca covering the superior mandible of *Pelecänus fuscus* has only in part been removed, and this also applies to the anterior two thirds of the mandible shown in Fig. 41. Beyond what has been mentioned above, in most other respects, the skulls of *P. fuscus* and *P. sharpei* are very much alike.

In the mandible the ramal symphysis is, for the size of the bone, altogether the weakest union of any in the entire Class *Aves*. For example, the ramus of the jaw in *P. sharpei* has a length of 34.5 centimeters, while the symphysis joining the two rami together, anteriorly, measures but 3 millimeters in any direction.

Explanation of Plates.

(All the specimens figured in the Plates (XXI.–XXX.) are reproductions of photographs made by the author, the material being in either his own private collection, or the collection of the United States National Museum.)

Plate XXI. Fig. 1. Dorsal aspect of the pelvis of *Plotus levaillanti.* Adult. (Coll. U. S. Nat. Museum No. 18,743.) Two of the pelvic ribs show upon the right side. Somewhat reduced; the mid-longitudinal line of this bone measures 9.5 cm. not including the ossified anterior tendinal extensions.

Fig. 2. Basal view of the skull of *Phaëthon æthereus*, adult, mandible removed, slightly reduced. Specimen in author's collection. From the island of San Pedro Martis, Gulf of California. Collected in April, 1889.

Fig. 3. Superior aspect of the skull of *Phaëthon flavirostris*, adult. (Coll. U. S. Nat. Musum No. 17,841.) Slightly reduced, the reduction being proportionate in amount with the skull shown in Fig. 2.

Fig. 4. Skeleton of left foot of *Fregata aquila*, adult. (Coll. U. S. Nat. Museum, No. 18,485.) Somewhat reduced. Sheath left on midanterior toe shows the " pectinated claw."

Fig. 5. Ventral view of the sternum of *Phaëthon æthereus*, adult (author's collection). Very slightly reduced. Collected in April, 1889. San Pedro Martis Isle, Gulf of California. The skull in Fig. 2 and this sternum are from two different individuals.

Fig. 6. Left lateral aspect of the trunk skeleton of *Phaëthon flavirostris*, adult. (Coll. U. S. Nat. Museum, No. 17,841.) Very slightly reduced. The skull shown in Fig. 2 belonged to this skeleton, but the reduction in the former is somewhat greater.

Plate XXII. Fig. 7. Right lateral view of the skull and mandible of *Sula gossi*, adult female (author's collection). Very slightly enlarged. Mandible detached. The superior mandible is tubular at the extremity and pervious at the apex. Collected at San Pedro Martis Island, Gulf of California, 16 Oct., 1888.

Fig. 8. Basal view of the skull of *Sula gossi*, adult female (author's collection). Very slightly reduced. Collected at same time and place as the specimen shown in Fig. 7.

Fig. 9. Basal view of the skull of *Sula Brewsteri.* Same specimen as shown in Fig. 7. Very slightly reduced. Left pterygoid bone dislocated inwards to show the form of the corresponding quadrate.

PLATE XXIII. Fig. 10. Superior aspect of the skull of *Sula gossi*. Mandible removed. Same specimen as the one shown in Plate II., Fig. 8. Very slightly reduced.

Fig. 11. Superior aspect of the skull of *Sula brewsteri*. Mandible removed. Same specimen as the one shown in Plate II., Fig. 9. Very slightly reduced, and in the same proportion as the skull shown in Fig. 10.

Fig. 12. Left lateral view of the trunk skeleton of *Sula gossi*. Reduced one third. Belonged to the same individual, which furnished the skull shown in Fig. 10.

PLATE XXIV. (All the bones figured in this plate are from the Coll. U. S. Nat. Mus. and their numbers are shown upon the specimens. They are all adult, and natural size.)

Fig. 13. Left lateral view of the skull of *Phalacrocorax pelagicus robustus*. Mandible removed. (See Fig. 18.)

Fig. 14. Left lateral view of the skull of *Phalacrocorax albiventris*. Mandible removed. (See Fig. 21.)

Fig. 15. Left lateral view of the skull of *Phalacrocorax urile*. Mandible removed. (Specimen bears no number.)

Fig. 16. Basal view of the skull of *Phalacrocorax melanoleucus*. Mandible removed (Australia). There is but one known species of cormorant in the world smaller than this one.

Fig. 17. Left lateral view of the skull and mandible of *Phalacrocorax dilophus*. Mandible detached. (See Fig. 19.)

Fig. 18. Superior aspect of the skull of *Phalacrocorax p. robustus*. Mandible removed. (See Fig. 13.)

Fig. 19. Superior aspect of the skull of *Phalacrocorax dilophus*. Mandible removed. (See Fig. 17.)

Fig. 20. Superior aspect of the skull of *Phalacrocorax melanoleucus*. Mandible removed. (See Fig. 16.)

Fig. 21. Superior aspect of the skull of *Phalacrocorax albiventris*. Mandible removed. (See Fig. 14.)

This series of specimens is designed to show the marked variation in form of the skull among the cormorants (*Phalacrocoracidæ*), ranging all the way from the much vertically compressed skull of *P. p. robustus* (Fig. 13) to the lofty skull of *P. albiventris* (Fig. 14).

PLATE XXV. Fig. 22. Dorsal view of the trunk skeleton of *Phalacrocorax urile*, with chain of cervical vertebræ naturally articulated but curved far backward and to the right. Reduced one half. The skull shown in Fig. 15 belonged to this skeleton.

Fig. 23. Left lateral view of the trunk skeleton of *Phalacrocorax urile*. Reduced one half, and the same specimen as shown in Fig. 22.

PLATE XXVI. Fig. 24. Anconal aspect of the right carpo-metacarpus of *Fregata aquila* (Specimen No. 18,485, Coll. U. S. Nat. Museum). Adult. Reduced; the actual extreme length of the bone being 13.2 cm.

Fig. 25. Left lateral view of the skull of *Phalacrocorax melanoleucus*. Mandible removed. Natural size. Same skull as shown in Plate IV., Fig. 20.

Fig. 26. Anconal aspect of the proximal phalanx of the medius digit of the manus of the right pectoral limb of *Fregata aquila*. Slightly reduced. From the same skeleton that the bone shown in Fig. 24 was obtained, with which it was distally articulated.

Fig. 27. Basal aspect of the skull of *Phalacrocorax dilophus*. Natural size. Same skull as the one shown in Fig. 17, Plate IV.

Fig. 28. Basal aspect of the skull of *Phalacrocorax p. robustus*. Natural size. Same skull as the one shown in Fig. 13, Plate IV.

Fig. 29. Basal aspect of the skull of *Phalacrocorax albiventris*. Natural size. Same skull as the one shown in Fig. 21, Plate IV. Note how much shorter the pterygoid bones are in this species as compared with the corresponding elements in the skulls shown in Figs. 27 and 28.

Fig. 30. Dorsal aspect of the sternum and os furcula of *Phalacrocorax albiventris* (No. 18,437, Coll. U. S. Nat. Museum). Reduced about one fifth. (See Fig. 21, Plate IV. Both from the same bird.)

PLATE XXVII. (*Pelecanus sharpei* and *Pelecanus fuscus*. Adults. All less than half natural size. *P. sharpei* is No. 18,736 of the Collection in the U. S. Nat. Museum, and *P. fuscus* (author's collection) was shot by me on Indian Cay, Bahama Banks, in 1864.)

Fig. 31. Anconal aspect, right ulna, *Pelecanus sharpei*.

Fig. 32. Anterior aspect, left femur, *P. sharpei*. Same specimen as Fig. 31 and the others on the Plate.

Fig. 33. Anterior aspect of the left tibio-tarsus, *P. sharpei*.

Fig. 34. Palmar aspect of left humerus, *P. sharpei*.

Fig. 35. Basal view of the skull of *P. fuscus*; mandible removed.

Fig. 36. Basal view of the skull of *P. sharpei*; mandible removed.

Fig. 37. Left lateral view of the skull of *P. sharpei*; mandible removed.

Fig. 38. Anterior aspect of the right coracoid; *P. sharpei*.

Fig. 39. Anconal aspect of the left carpo-metacarpus, *P. sharpei*.

Fig. 40. Superior view of the skull of *P. fuscus*; mandible removed; same specimen as Fig. 35, and the mandible shown in Fig. 41.

Fig. 41. Superior view of the mandible of *P. fuscus*. (See Fig. 40.) The three bits of wax supporting this bone show beneath the articular cups and the symphysis.

PLATE XXVIII. Fig. 42. Dorsal aspect of the sternum and the coössified os furcula of *Pelecanus sharpei;* reduced about one fifth. No. 18,736, Collection in the U. S. Nat. Museum. See Figs. 31, 32 and others of Plate VI. Same skeleton.

Fig. 43. Palmar aspect left pectoral limb of *Phalacrocorax urile.* Reduced about one fourth. From the same skeleton that furnished the skull shown in Fig. 15, Plate IV., and the trunk skeleton shown in Figs. 22 and 23, Pl. V.

Fig. 44. Inner aspect of the right pelvic limb of *Phalacrocorax urile.* Reduced about one fourth from the same skeleton that furnished the pectoral limb shown in Fig. 43.

PLATE XXIX. (Skull, including mandible of *Fregata aquila.* No. 18,485 of the Coll. U. S. Nat. Museum. Adult. All slightly reduced; Fig. 46 more so than the others.) Total length of skull 17.3 centimeters, and ramus of mandible 16.5 cm.

Fig. 45. Left lateral view of the skull; mandible detached.

Fig. 46 Superior view of the skull; mandible removed.

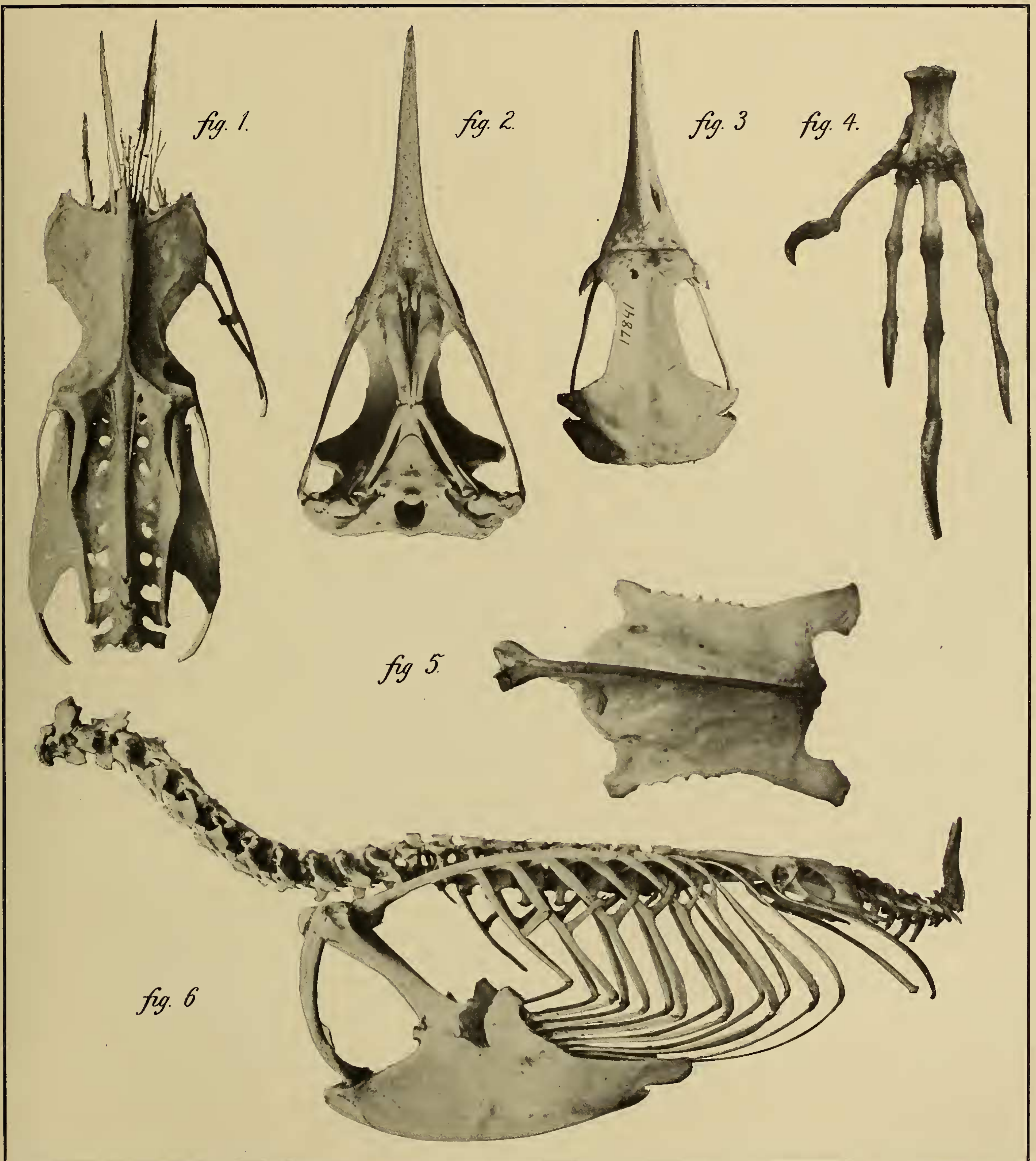
Fig. 47. Superior view of the mandible.

Fig. 48. Basal view of the skull; mandible removed. For other bones of the skeleton of this individual see Plate I., Fig. 4; Plate VI., Figs. 24, 26; Plate X., Figs. 50 and 51. In Fig. 48 the right quadrate bone and the pterygoid of the same side have been removed.

PLATE XXX. Fig. 49. Ventral aspect of the pelvis of *Pelecanus sharpei;* considerably reduced. The longitudinal median line of the vertebral portion of this bone measures about 19.5 cm. It is from the same skeleton that furnished the bones shown in Plate VII.

Fig. 50. Ventral aspect of the sternum and shoulder-girdle of *Fregata aquila;* slightly reduced. See remarks under Fig. 48, Pl. IX.

Fig. 51. Left lateral aspect of the sternum of *Fregata aquila.* Natural size. See remarks under Plate IX. and Fig. 48.



SHUFELDT. OSTEOLOGY OF THE STEGANOPODES. PLATE I.

fig. 7.

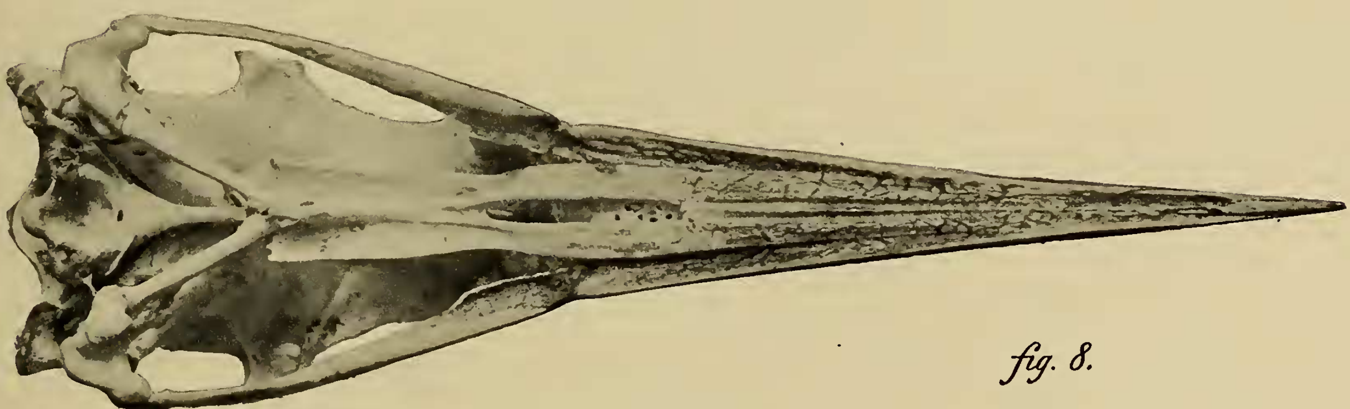


fig. 8.

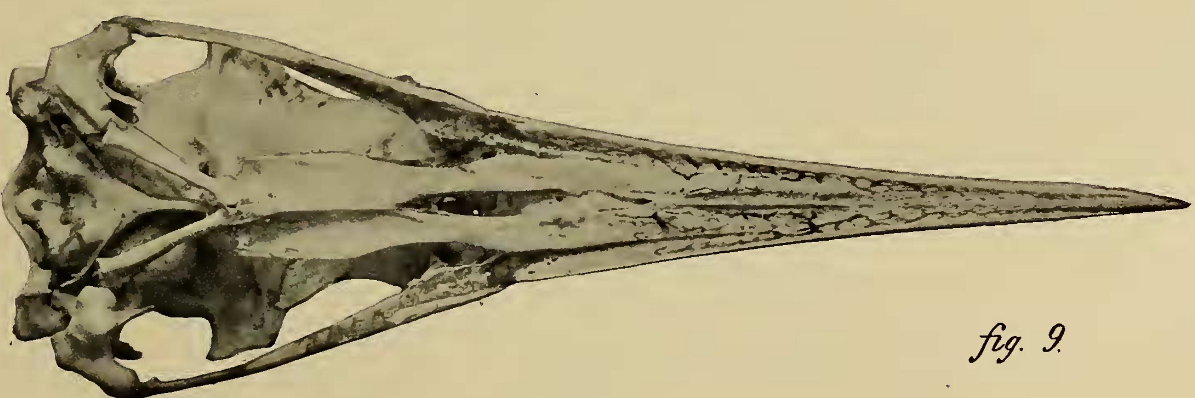
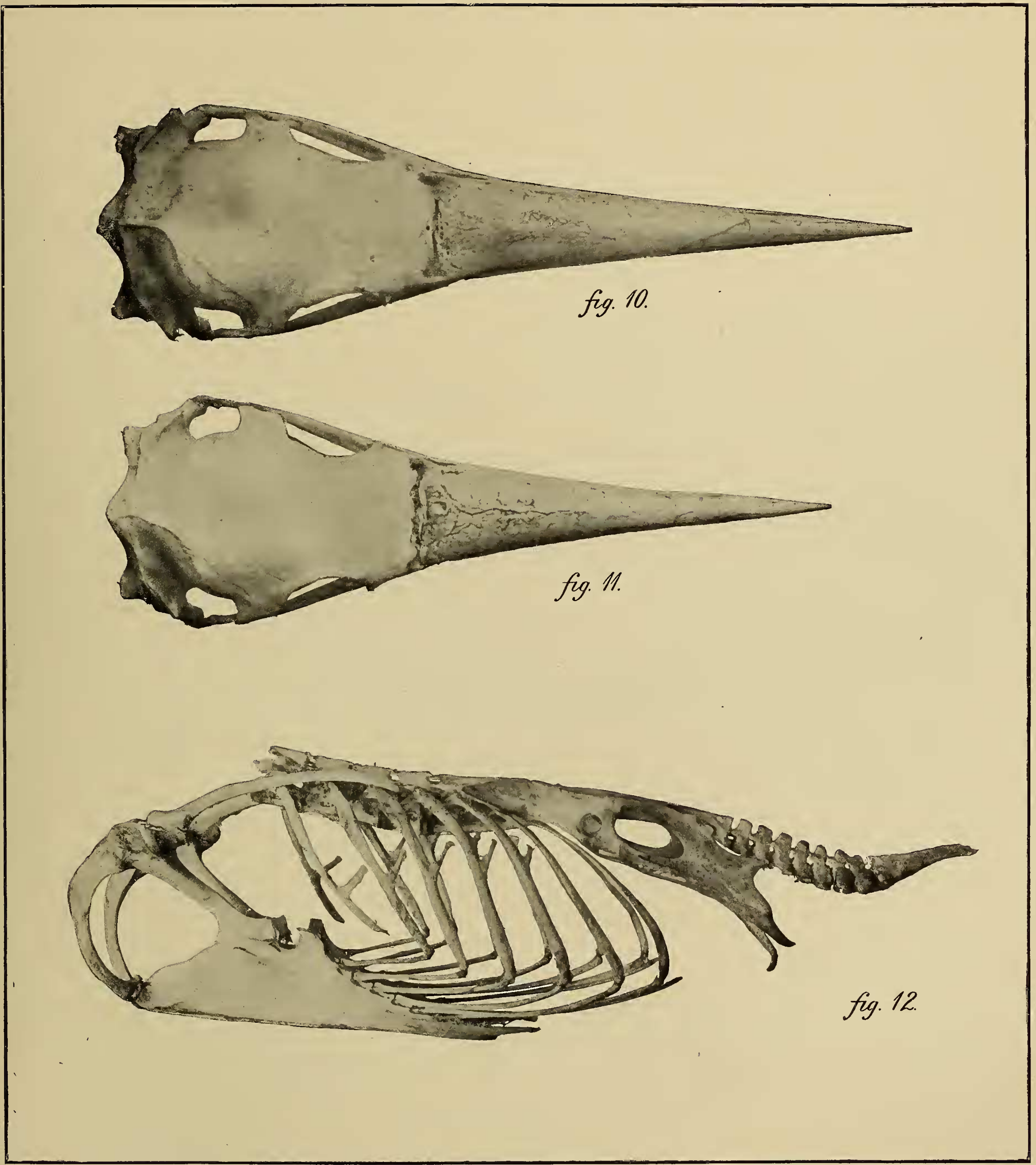
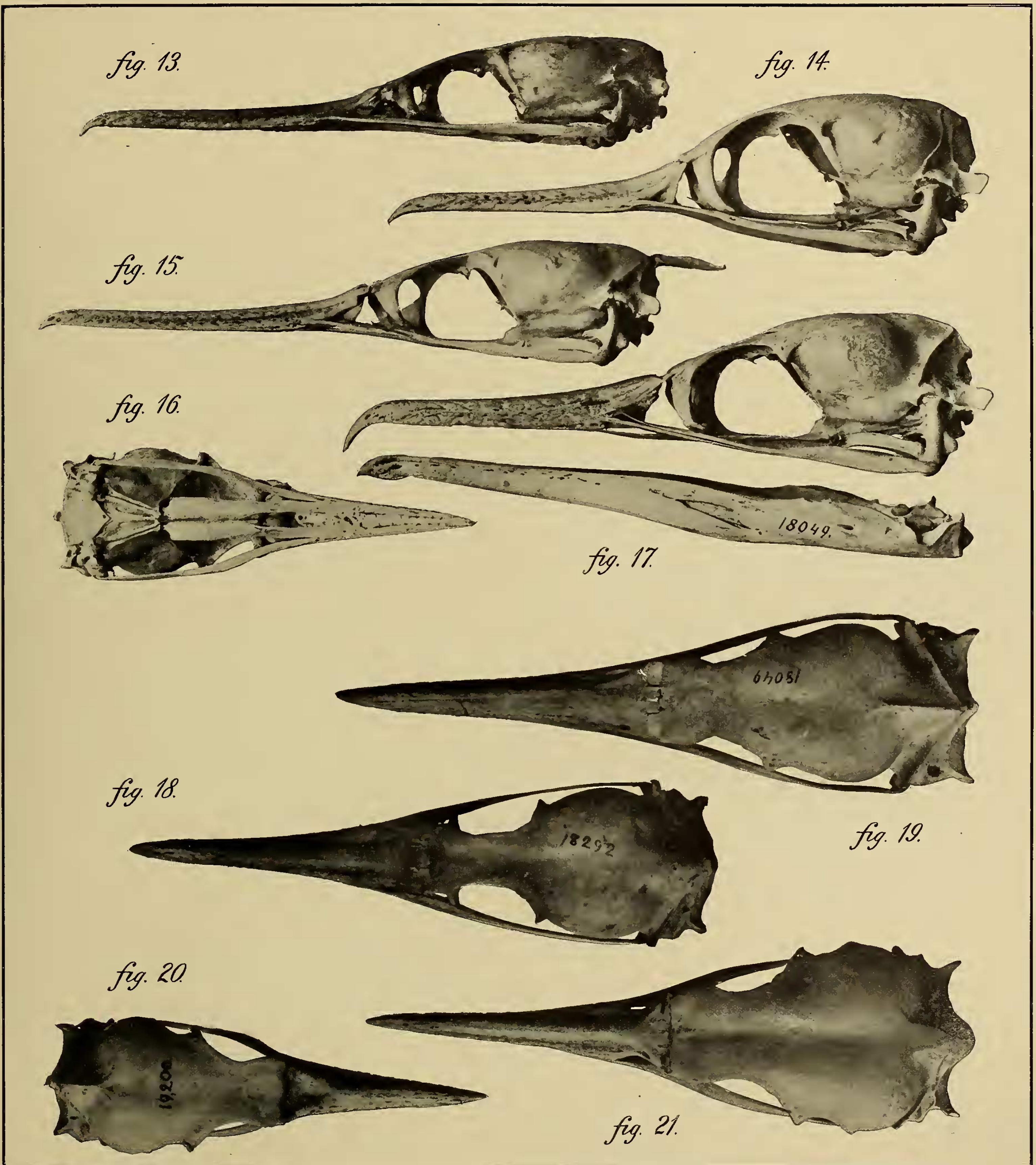


fig. 9.



SHUFELDT. OSTEOLOGY OF THE STEGANOPODES. PLATE III.



SHUFELDT. OSTEOLOGY OF THE STEGANOPODES. PLATE IV.

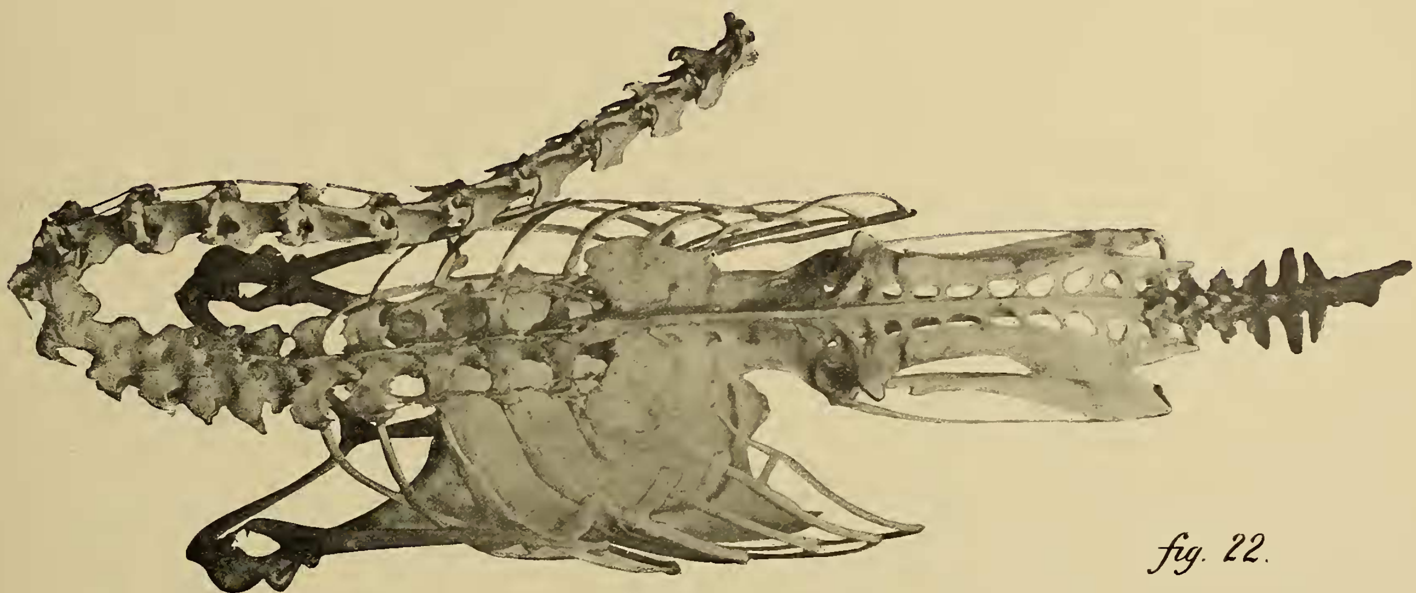


fig. 22.

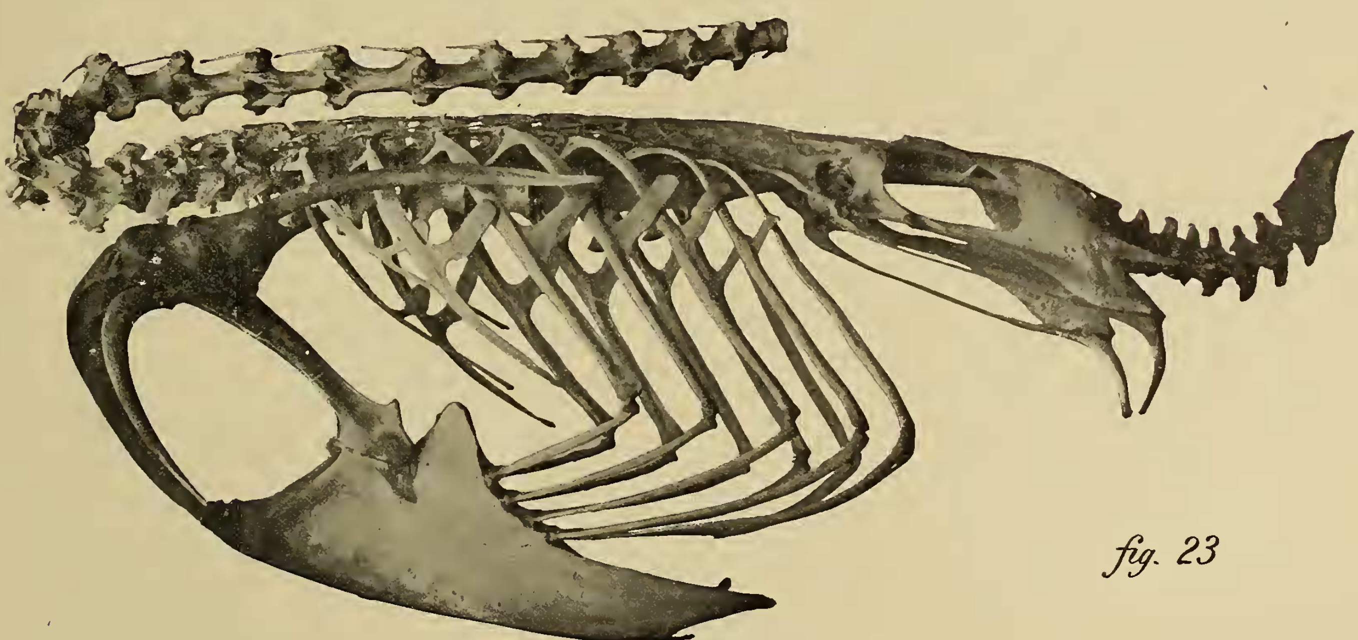
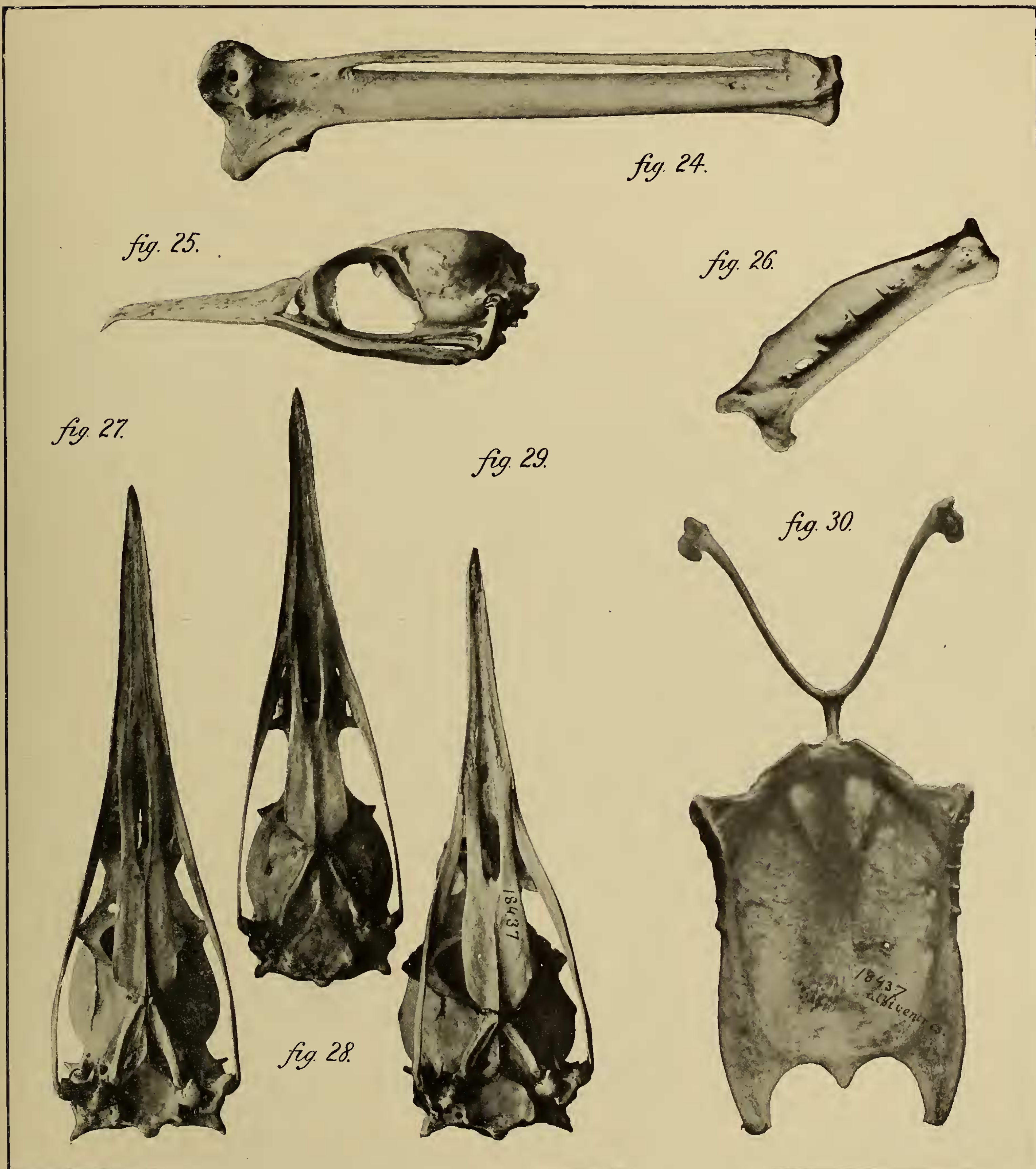
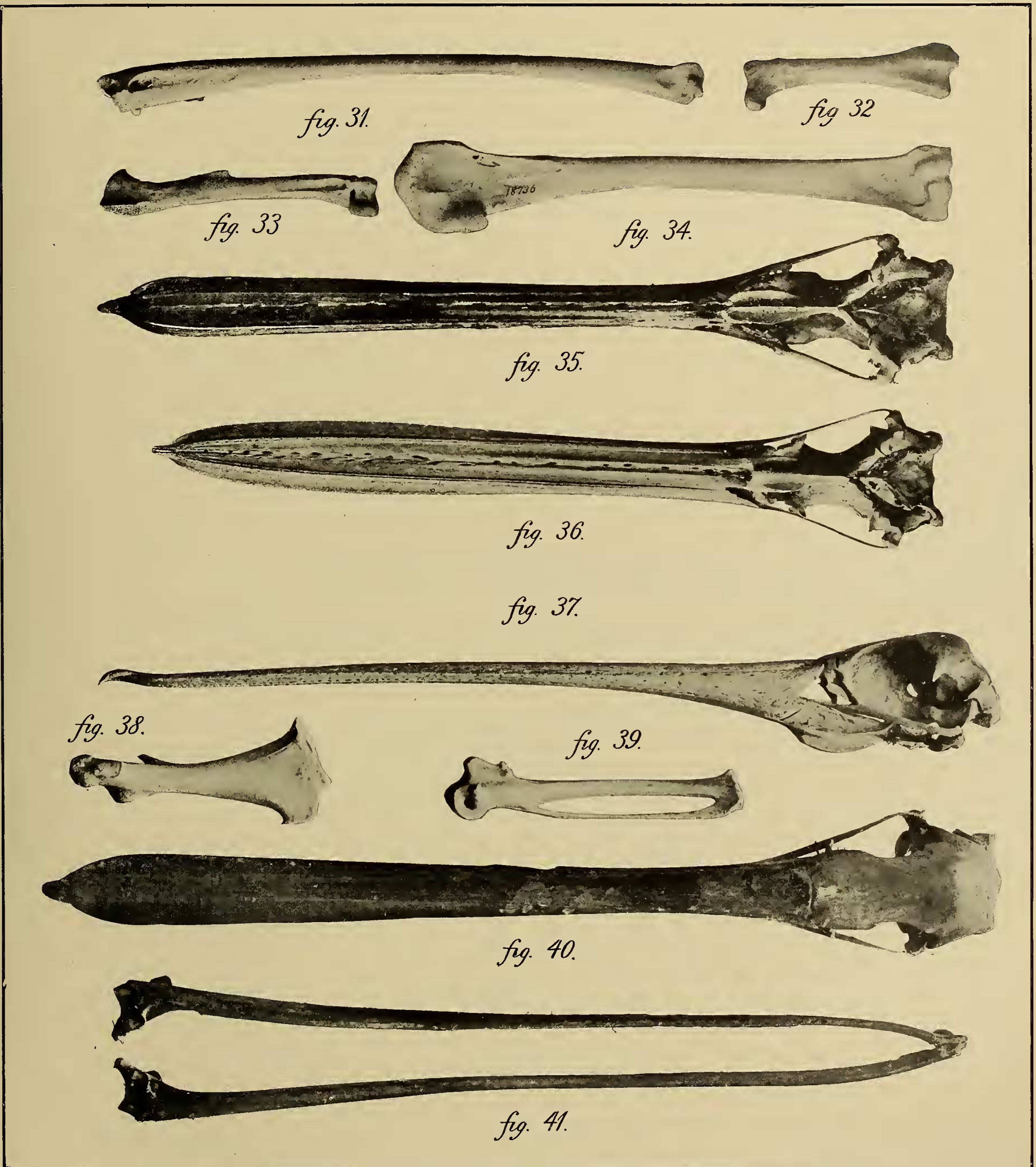


fig. 23

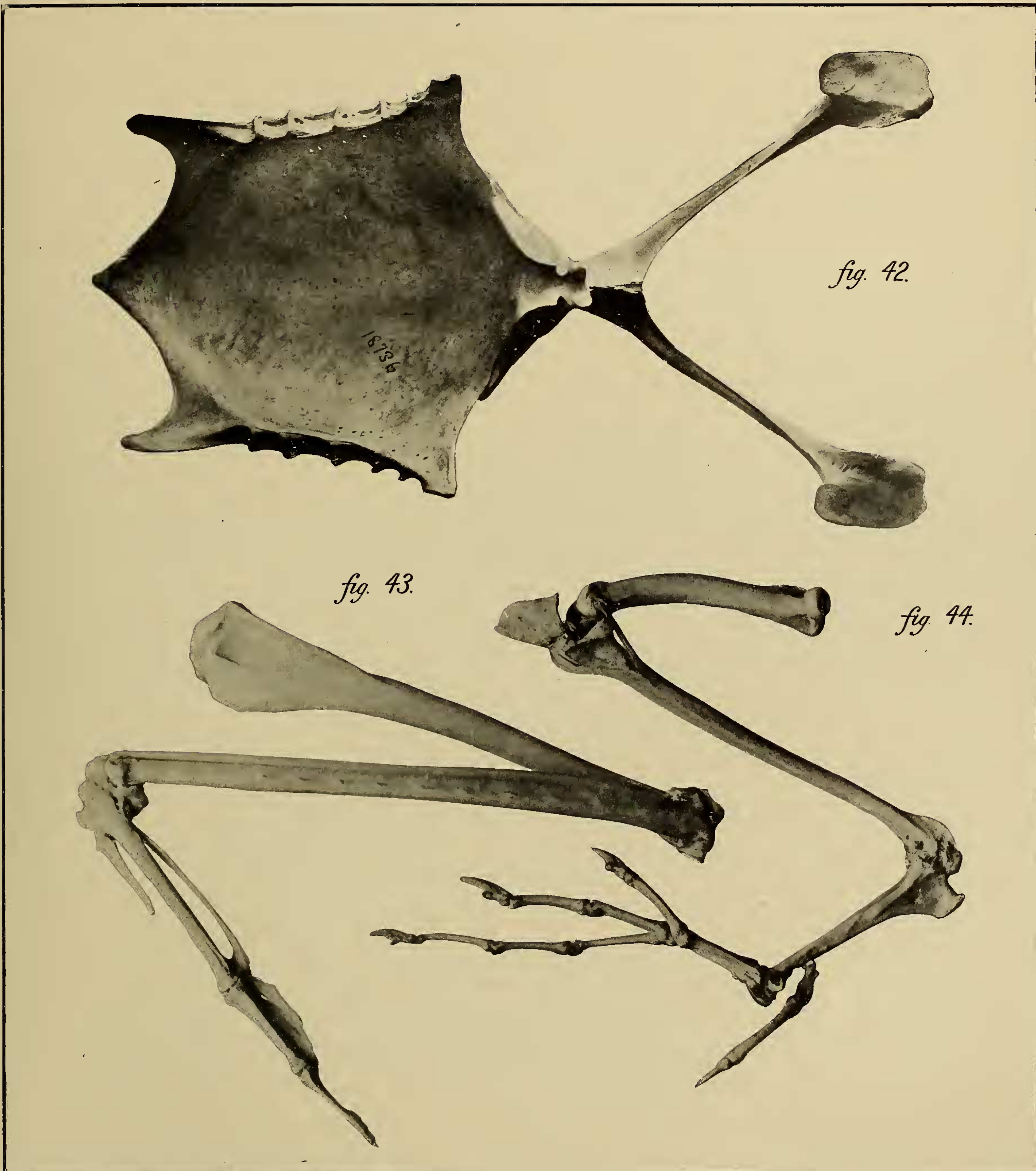
SHUFELDT. OSTEOLOGY OF THE STEGANOPODES. PLATE V.



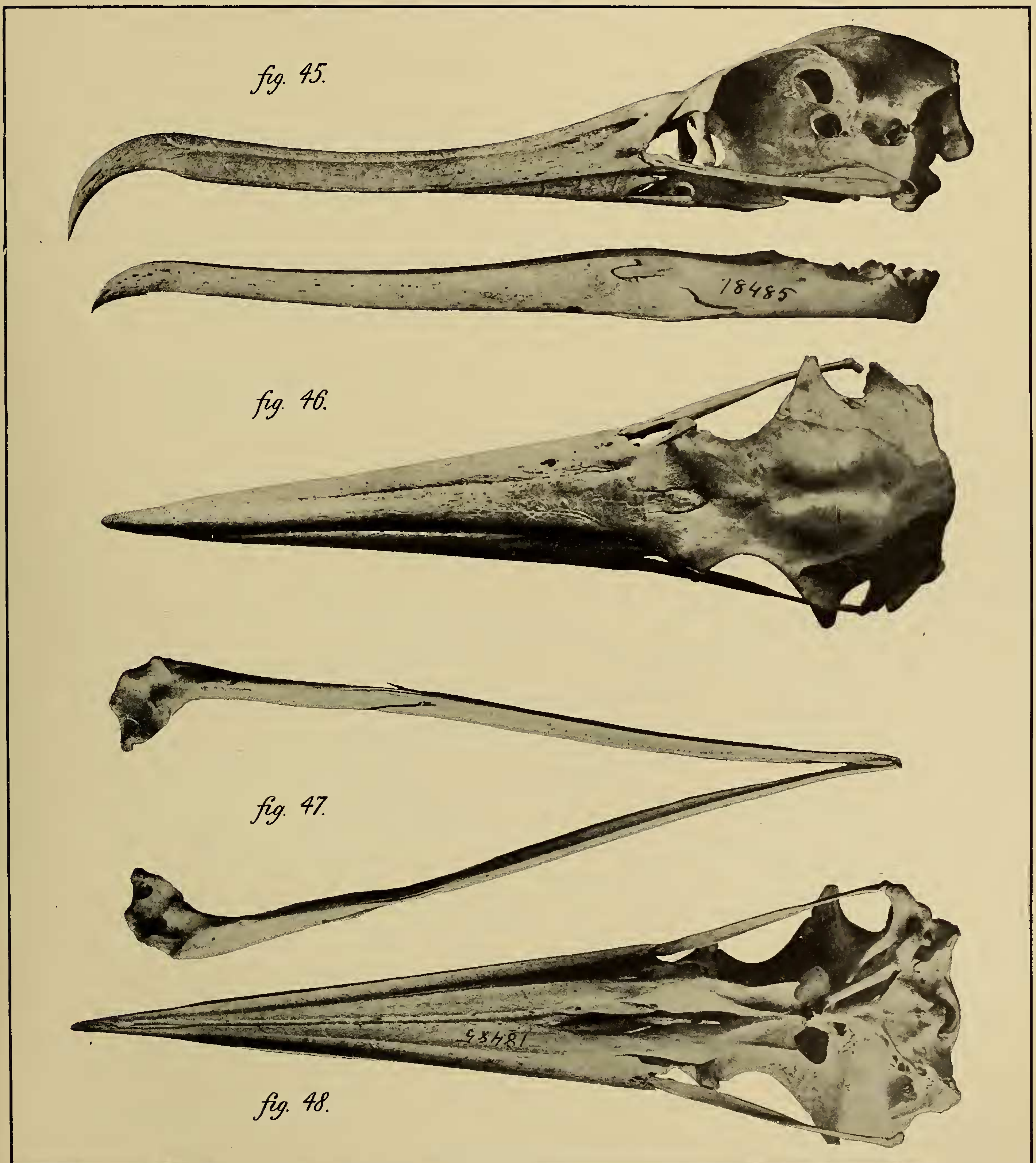
SHUFELDT. OSTEOLOGY OF THE STEGANOPODES. PLATE VI.



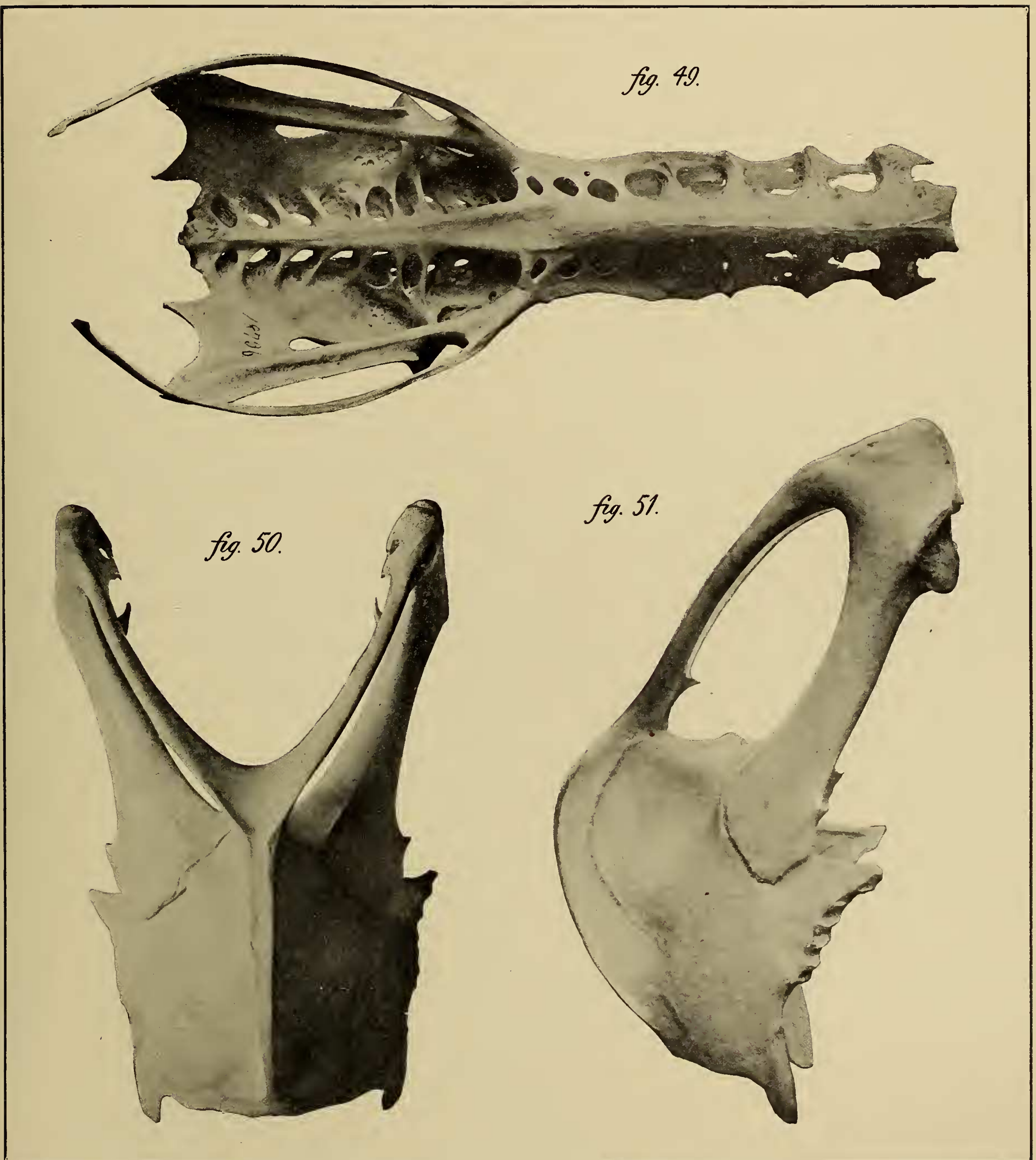
SHUFELDT. OSTEOLOGY OF THE STEGANOPODES. PLATE VII.



Shufeldt. Osteology of the Steganopodes. Plate VIII.



Shufeldt. Osteology of the Steganopodes. Plate IX.



Shufeldt Osteology of the Steganopodes. Plate X.